Winter 2008

Conserving dolphins and fishermen: Combining science and local knowledge to reduce cetacean bycatch

Erika A. Zollett
University of New Hampshire, Durham

CONSERVING DOLPHINS AND FISHERMEN: COMBINING SCIENCE AND LOCAL KNOWLEDGE TO REDUCE CETACEAN BYCATCH

BY

ERIKA A. ZOLLETT
Bachelor of Science, Bates College, 2000
Master of Environmental Management, Duke University, 2004

DISSERTATION

Submitted to the University of New Hampshire
in Partial Fulfillment of
the Requirements for the Degree of

Doctor of Philosophy
in
Natural Resources and Earth Systems Science

December 2008

UMI Number: 3348321

This dissertation has been examined and approved.

Dissertation Director,
Dr. Andrew A. Rosenberg,
Professor of Natural Resources

Dr. Andrew B. Cooper,
Associate Professor, Simon Fraser University,
Affiliate Research Assistant Professor of
Natural Resources and Earth Systems Science

Dr. Chris Glass,
Director of Northeast Consortium,
Research Professor of Zoology

Dr. Andrew J. Read,
Associate Professor of Marine Conservation
Biology,
Nicholas School of the Environment,
Duke University

Dr. Madeleine Hall-Arber,
Anthropologist,
Center for Marine Social Sciences,
Massachusetts Institute of Technology,
Sea Grant College Program

8 December / 2008
Date

ACKNOWLEDGEMENTS

Many people helped to make this research possible. First, I would like to thank my advisor, Dr. Andrew Rosenberg, whose guidance, support, and encouragement made it all possible. I could not have asked for a more supportive or more generous advisor. I would also like to thank my committee members. Dr. Andrew Cooper worked tirelessly and patiently with me to grasp the statistical concepts used throughout this study. Dr. Madeleine Hall-Arber generously donated her time to making sure I spoke the same language as fishermen, and that my methodology was consistent with social science and anthropology disciplines. She also provided thorough edits that helped strengthen this dissertation. Drs. Andrew Read and Chris Glass also provided crucial guidance in this research.

I would like to thank the Northeast Fisheries Observer Program for use of the observer data. I would also like to acknowledge Chris Orphanides at the National Marine Fisheries Service who was instrumental in making this research possible. Chris provided much of the data that was used in the study. Other technical assistance was provided by Jim Manning, Joan Palmer, Tim Miller, Richard Merrick, Debi Palka, Ben Galuardi, Michael Routhier, and Ernst Linder.

This study would not have been possible without the New England bottom trawl fishermen. Their willingness to share their knowledge, experiences, and perspectives have made me a better scientist and a more effective conservationist.

This study was funded by the Northeast Consortium and the United States Marine Mammal Commission. Other travel and research funds were also provided by the University of New Hampshire Graduate School, Marine Program, and Natural Resources and Earth Systems Science graduate program.

Finally, I would like to thank my family for their unconditional love and support, which helped me get through many of the challenges I faced during this study. They taught me that I can do anything that I put my mind to. I thank Eric, my husband, for being my partner in this experience and in life.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

CONSERVING DOLPHINS AND FISHERMEN:
COMBINING SCIENCE AND LOCAL KNOWLEDGE
TO REDUCE CETACEAN BYCATCH

By

Erika A. Zollett

University of New Hampshire, December, 2008

Bycatch is the portion of catch that is neither targeted nor retained by fishermen. It threatens the survival of many marine mammal populations globally, and it occurs in nearly every fishing gear type. Despite its widespread occurrence, observations of bycatch are rare, and scientific data on marine mammal bycatch are limited. Difficulties result in developing models that accurately depict the interactions. This study focuses on developing methodology to combine disparate data sources, specifically data from fishery observer programs and interviews of fishermen, to better understand these interactions and to identify effective mitigation measures. As a case study, this research investigates the spatial and temporal patterns associated with Atlantic white-sided dolphin (*Lagenorhynchus acutus*) bycatch in the New England bottom trawl fishery for groundfish to aid in the development of an effective bycatch reduction plan. A quasi-binomial model of the fishery observer data was developed using environmental and fishing-related covariates to describe the probability of dolphin bycatch in this fishery. Significant variables in describing dolphin bycatch included sea surface temperature ($p<0.001$), depth ($p<0.001$), and an interaction between bottom slope and depth ($p<0.05$). The model was mapped using geographic information systems and incorporated into interviews with bottom trawl fishermen to facilitate discussion on patterns of bycatch. Thirty-one bottom trawl fishermen were interviewed, and results were consistent with the probability model that bycatch was rare and was more likely to occur in offshore fishing areas. Interviewed fishermen did not relate bycatch to environmental variables and did not provide consistent responses regarding spatial or temporal patterns associated with these events. As a result, this study was unable to develop methodology to spatially combine these data sources. However, fishermen did provide useful information to scientists and fishermen. For instance, interview results suggested that area-based management would not be effective in this fishery, contrary to the results of the probability model, due to the occurrence of bycatch throughout the fishing area. Instead broad-scale measures, coupled with incentives, would be a more effective mitigation measure in this fishery. Collaborative research between fishermen and scientists or gear technologists is recommended to better understand operational patterns associated with bycatch.

CHAPTER I

UNDERSTANDING BYCATCH TO DESIGN EFFECTIVE MITIGATION STRATEGIES

Introduction

Incidental capture in fishing activities threatens marine mammals worldwide in nearly every type of fishing gear (Northridge 1991, Read and Rosenberg 2002). An incidental capture of a marine animal, also referred to as incidental take or bycatch, is the portion of catch that is not targeted and that has no economic value, either because no markets exist for a species or because its retention is prohibited by law (Hall 1996). Bycatch has negative consequences for fishermen including gear damage, lost fishing time, lost income, and even safety concerns (Hall 1996). Direct consequences to bycaught marine life include injury and death. The first global bycatch estimate predicts hundreds of thousands of marine mammals are incidentally captured annually (Read et al. 2006). This incidental capture poses the greatest conservation threat worldwide to many marine mammal populations (Read et al. 2006). Bycatch creates a problem, which if ignored, is predicted to cause the extinction of several species and populations in the next few decades (Northridge 1991, Read and Rosenberg 2002). For instance, bycatch is the leading threat to endangered marine mammals, including the vaquita (*Phocoena sinus*) and Hector's dolphin (*Cephalorhynchus hectori*), and is a contributing conservation concern for dwindling populations of the Mediterranean monk seal (*Monachus monachus*) and the North Atlantic right whale (*Eubalena glacialis*) (Read et al. 2006).

With an increasing global human population and the corresponding need for fish resources, fishing in both coastal and pelagic waters will likely increase, intensifying the interactions between fisheries and marine mammal populations due not only to competition for resources but also to simple spatial overlap (Read 2005). Thus, it is of utmost importance for research to concentrate on the characteristics, including causes and patterns, of bycatch in order to identify potentially effective strategies to mitigate the problem.

Trawl Fisheries

Bycatch occurs in fisheries ranging from artisanal to industrial in nature throughout the world due to an overlap in distribution and utilization of areas with high prey density by marine mammals and fisheries (Fertl and Leatherwood 1997, Read and Rosenberg 2002). Nearly every fishing gear type, including gillnets, longlines, purse seines, and trawl nets incidentally capture marine mammals throughout the world's oceans (Northridge 1991, Read and Rosenberg 2002). This dissertation will investigate the characteristics of marine mammal bycatch, specifically of cetaceans, occurring in trawl fisheries.

In a preliminary review of available global bycatch data, Fertl and Leatherwood (1997) indicate that twenty-five species, including twenty-three odonotocete and two mysticete species, have been reportedly killed in working trawls or discarded trawl gear. Previous research on bycatch in trawl fisheries has focused on odontocetes including common dolphins (*Delphinus delphis*) (Waring et al 1990; Couperus 1997; Tregenza and

Collet 1998; Morizur et al. 1999; Northridge 2003a,b, Northridge et al. 2003), pilot whales (*Globicephala spp.*) (Waring et al. 1990, Couperus 1997), bottlenose dolphins (*Tursiops spp.*) (Waring et al. 1990, Couperus 1997, Tregenza and Collet 1998, Morizur et al. 1999), Atlantic white-sided dolphins (*Lagenorhynchus acutus*) (Waring et al. 1990, Couperus 1997, Tregenza and Collet 1998, Morizur et al. 1999), harbor porpoise (*Phocoena phocoena*) (Kastelein et al. 1997a,b, de Haan et al. 1998), dusky dolphins (*Lagenorhynchus obscurus*) (Crespo et al. 1997, Dans et al. 1997), white-beaked dolphins (*Lagenorhynchus albirostris*) (Couperus 1997), Commerson's dolphins (*Cephalorhynchus commersonii*) (Crespo et al. 1997), Dall's porpoise (*Phocoenoides dalli*) (Loughlin et al. 1983) and Risso's dolphins (*Grampus griseus*) (Waring et al. 1990); mysticete species including right whales (Waring et al. 1990); and pinniped species including grey seals (*Halichoerus grypus*) (Tregenza and Collet 1998, Berrow et al. 1998, Morizur et al. 1999), southern sea lions (*Otaria flavescens*) (Crespo et al. 1997), northern sea lions (*Eumetopias jubatus*) (Loughlin et al. 1983), Hookers sea lions (*Phocarctos hookeri*) (Slooten and Dawson 1995, Gibson and Isakssen 1998), and New Zealand fur seals (*Arctocephalus forsterii*) (Loughlin et al. 1983, Gibson and Isakssen 1998). Some of these studies will be discussed in this paper.

In the past several decades, the expanded use of trawl nets and the increased rate of marine mammal bycatch may have resulted from improved technology such as the introduction of large freezing and factory vessels that allow vessels to fish longer and farther from shore (Waring et al. 1990, Crespo et al. 1997). For instance, a distant-water fleet (DWF) from Europe and Japan began fishing off of the east coast of the United States in the early 1960's, harvesting groundfish and pelagic species and utilizing several different off-bottom pelagic trawls. Trawl gear was predominately used by foreign groundfish vessels that once fished in U.S. waters of the North Pacific Ocean and Bering Sea (Bakkala et al. 1979). Since the early 1980's, pelagic trawling has become prevalent in the Northeast Atlantic and has displaced other fishing methods (Tregenza and Collet 1998). In a study in north and central Patagonia, trawl gear was used by 80% of all vessels, making it the most common fishing gear type (Crespo et al. 1997). Today, trawl fishing has even become common in African countries. Along the West African coast, large commercial bottom and midwater trawlers come from far away foreign nations including Japan, Korea, Spain, Portugal, Romania, and the Russian Federation (Maigret 1994). Trawl gear is used throughout the western Indian Ocean to catch shrimp by countries including Kenya, Madagascar, Mozambique, South Africa, and Tanzania (Fennessy et al. 2004).

Trawl fishing gear utilizes a funnel-shaped net which is towed through the water by either one or two boats (using two boats is known as pair trawling) to harvest fish, squid, shrimp, and crustaceans (Fertl and Leatherwood 1997, Sea Grant 2003). Water passing over large metal doors attached to the front of the trawl widely opens the mouth of the net, allowing catch to enter; the net slowly tapers in size until the cod end where the catch is collected (Sea Grant 2003). Trawl vessels operate gear differently depending on the fishery, location, and depth (Tregenza and Collet 1998). Trawl fishing gear is generally classified by the type of trawl: surface, bottom, or mid-water (Crespo et al. 1997, Fertl and Leatherwood 1997). Bottom trawls usually operate at 2.5 to 3 knots while often larger mid-water trawls are pulled at faster speeds to catch fast-swimming, schooling fish (Chris Glass, pers. comm., October 2008). Trawl gear can be modified by depth or duration of a set, speed of tow, size of mesh, size of mouth, type of net, and time of operation, either diurnal or nocturnal, in order to target a particular fish species (Crespo et al. 1997). Of particular importance to marine mammal species, the characteristics of trawl gear and location of a set can likely be modified to avoid or reduce bycatch.

Interactions

Interactions between trawl gear and marine mammals occur throughout the world's oceans, wherever the two overlap in distribution. Estimates of bycatch are usually predicted using data from a sample of the fishery. Morizur et al. (1999) explain that where bycatch is not recorded does not mean that the conflict is not occurring. Fishermen often fail to report all incidences of bycatch (Loughlin et al. 1983), and observer coverage differs between fisheries and countries throughout the world. In Portugal, reports of bycatch by fishermen decreased when bycatch became illegal even though no action was taken to reduce bycatch (Sequeira and Ferreira 1994). In addition, many fisheries throughout the world are not observed so it is expected that under-reporting of cetacean bycatch occurs. It is also likely that marine mammals fall out of fishing nets or are thrown overboard in some cases and are not included in bycatch estimates. Occasionally, marine mammals wash up on beaches with certain marks or amputations that suggest the animals died as a result of bycatch, but it is often hard to determine which fishery, if any, is responsible (Tregenza and Collet 1998). Some fisheries use a pump to transfer fish catch from the trawl net to the boat (Tregenza and Collet 1998). In these cases, the nets never leave the water, and marine mammals are too large to fit into the pump. The presence of marine mammals in the net may only be detected if a part of the animals is amputated, such as the flukes, and brought aboard via the pump (Tregenza and Collet 1998).

As previously mentioned, there are negative consequences of bycatch to fishermen and to marine mammals. The interactions between cetaceans and trawl gear can cause injury or death to animals; create negative opinions of, and possibly negative actions to, marine mammals by fishermen; and cost fishermen time and money to repair and/or replace damaged gear and to disentangle and discard entangled animals. Angry fishermen may take action against marine mammals to protect their gear and catch. For instance, a small number of bottlenose dolphins are caught in shrimp trawls in the Gulf of Mexico, and occasionally, fishermen have been known to shoot dolphins to avoid gear damage (Northridge 1991). Fishermen have also been observed shooting at dolphins to protect their catch (Zollett and Read 2006). Bycatch and retaliatory measures by fishermen may also create negative perceptions toward the fishermen or their catch from consumers, who may chose not to buy a product due to its impact on marine mammals. For instance, public outrage about dolphin bycatch in the tuna purse-seine fishery, which will be discussed later in this dissertation, resulted in consumer boycotts of tuna products and led to the adoption of dolphin safe fishing techniques.

Trawl gear can also result in environmental effects, including habitat damage and changes in ecosystem structure, in addition to direct impacts, such as injury or death, to marine mammals. The presence of trawl gear may disadvantage marine mammals due to depletion of prey stocks and shifts in available prey in an ecosystem; however, marine mammals may also capitalize on fishing activities by feeding on catch or discards from fishing efforts and thus, reducing their own time spent foraging (Leatherwood 1975, Fertl and Leatherwood 1997, Broadhurst 1998, Pace et al. 2003). By exploiting fisheries, marine mammals may access food usually too deep, fast, or energetically costly to capture themselves (Fertl and Leatherwood 1997).

Bycatch Characteristics

Cetaceans caught in trawl gears may be dying or already dead when picked up by passing trawl nets (Loughlin et al. 1983); however, most evidence suggests that bycaught marine mammals are healthy when entanglement occurs. In Danish fisheries, using unspecified gear types, bycaught harbor porpoises were classified as healthy at the time of death; therefore, researchers believe the animals became entangled in the nets while alive (Larsen and Holm 1996). Reports indicate that eighteen bycaught cetaceans, including common dolphins, Atlantic white-sided dolphins, and one possible bottlenose dolphin, were captured in four of eleven observed fisheries in the northeast Atlantic (Tregenza and Collet 1998, Morizur et al. 1999). Although all animals had died and were found free within the net, with the exception of one entangled individual, all cetaceans appeared to be healthy at the time of capture.

Causes

Trawling activities can attract healthy animals since they represent an easy-to-access, concentrated food source. As previously mentioned, trawling may open a niche of previously unexploited food resources, such as fish species that are too fast, deep, or energetically costly to capture to cetaceans, or trawling may provide an abundance and diversity of food with a high caloric value (Fertl and Leatherwood 1997). For instance, the occurrence of Atlantic mackerel (*Scomber scombrus*) in the stomachs of pilot whales and the high mortality rate of these whales in the northeastern U. S. mackerel trawl fishery suggests the importance of mackerel in the diet of these animals (Waring et al. 1990). However, pilot whales do not normally prey on mackerel, suggesting the whales are opportunistic in exploiting trawlers (Waring et al. 1990).

In all areas of the world, associations between at least 15 cetacean species and trawlers have been documented (Fertl and Leatherwood 1997). Leatherwood (1975) observed three feeding patterns of bottlenose dolphins associated with shrimp trawlers including animals foraging behind working boats, eating organisms stirred-up from trawlers, fish that bypass the net, or fish stuck in the mesh; animals feeding on discarded fish or those that escaped the net; and animals preying on fish attracted to non-working trawlers. For instance, Leatherwood (1975) observed bottlenose dolphins feeding on northern anchovies (*Engraulis mordax*) that were discarded from shrimp trawlers, and he observed groups of four to six dolphins chasing small schools of unidentified bait near anchored fishing vessels. Similarly, Pace et al. (2003) observed bottlenose dolphins associating with trawlers in four phases: following the trawls, feeding on the net, waiting for trash fish, and feeding on discarded, trash fish. Prey associated with trawling gear may be dead, injured, or disoriented, making it easy for cetaceans to capture them with low energy expenditures. Broadhurst (1998) observed groups of up to five bottlenose dolphins, swimming directly behind the cod end of commercial prawn trawl nets and using their rostrums and foreheads to shake the nets, releasing the catch of mostly juvenile whiting (*Sillago* spp.). The dolphins ate the drifting, released catch and those caught in mesh, but the dolphins did not chase or consume escaped, live whiting (Broadhurst 1998).

Whether a cetacean is feeding primarily on the target species of or on species associated with trawling activities may determine the amount of time and energy that is expended on foraging behaviors. For instance, Chilvers and Corkeron (2001) and Chilvers et al. (2003) studied two communities of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Moreton Bay, Australia with overlapping distributions. The two communities, referred to as "trawler" and "nontrawler" dolphins, show complete social segregation and varying behaviors towards prawn trawlers. The behavioral budget of the trawler community, which occurred in larger schools than nontrawler dolphins, differed greatly from those normally reported for this species (Chilvers and Corkeron 2001, Chilvers et al. 2003). The trawler community spent a large proportion of time foraging, possibly due to limited resources as a result of trawling or possibly since trawler dolphins rely on stirred-up organisms or on discards (Chilvers et al. 2003). Feeding on discards would require dolphins to follow trawlers for many hours, explaining the foraging time expended by trawler dolphins.

On the other hand, it is also possible that by taking advantage of concentrated fish resources, marine mammals may decrease the time they spend foraging (Fertl and Leatherwood 1997, Pace et al. 2003). Stomach contents of incidentally captured cetaceans suggest that they may be taking advantage of trawl fisheries; however, it is also possible that the animals are feeding on the same species and utilizing the same high prey density areas targeted by trawl fisheries, making them more susceptible to capture. Berrow et al. (1998) found bycaught grey seals were feeding on herring (*Clupea harengus*) targeted by trawl nets at the time of death. Similarly, Waring et al. (1990) found the stomach contents of common dolphins caught in mid-water trawls for Atlantic mackerel and squid (*Illex illecebrosus and Loligo pealei*) to be consistent with the species targeted by the trawlers. Stomach contents also suggested *L. pealei* is also a major component of the diet of pilot whales, also bycaught in trawl operations off the northeast coast of the United States (Waring et al. 1990). White-sided dolphins captured in the Dutch mid-water trawl fishery, southwest of Ireland, contained intact or partly digested fish in their stomachs, most of which was mackerel, the target species of the fishery (Couperus 1997).

Marine mammals may be susceptible to incidental capture in trawl gear for reasons other than feeding on the same species that are targeted by trawlers. For instance, they may not be feeding on a target species but on an associated non-target species. Crespo et al. (1997) found most of the dusky and Commerson's dolphins caught off of the Patagonian coast could be attributed to shrimp trawling operations although no shrimp were found in the stomachs of the dead animals. Instead, anchovy (*Engraulis spp.*), a shrimp-associated species, was the primary prey of the captured dolphins. Marine mammals may be found in proximity to trawl gear due to an attraction to species that are preying on the caught fish (Fertl and Leatherwood 1997). As previously discussed, marine mammals may also be in the vicinity of trawl gear, feeding on organisms stirred-up from bottom trawls or preying on discarded bycatch (Leatherwood 1975, Fertl and Leatherwood 1997, Broadhurst 1998). Loughlin et al. (1983) found a high incidental capture of northern sea lions since the animals followed fishing vessels while scavenging on discarded fish and interfered with the net during other aspects of the fishing operation.

The behavior of marine mammals while feeding on or in the proximity to trawl nets likely plays a role in leading to their capture. Bottlenose dolphins were observed foraging at night on fish species attracted to the waters illuminated by vessels' lights, placing them in close proximity to fishing gear (de Haan et al. 1998). Morizur et al. (1999) observed white-sided dolphins and grey seals feeding around trawl nets during towing, making the animals more vulnerable to capture. Grey seals were seen regularly preying on targeted herring during hauling and were often observed diving between pair trawlers during towing, suggesting the animals can usually avoid capture but occasionally become trapped (Berrow et al. 1998). Waring et al. (1990) observed pilot whales pursuing mackerel and feeding in and around the mouth of active trawl nets during haulback. Northridge et al. (2004) observed bottlenose dolphins facing oncoming water inside trawl nets, feeding on fish. It was apparent that animals entered the net to take advantage of captured fish; the animals entered and left the net at will. One sighting, captured on camera, observed animals inside the net for over an hour.

These behaviors of marine mammals in or around trawl nets may be carried on to future generations through cultural transmission of knowledge. Female cetaceans with calves have been observed following trawl boats; therefore, calves may be learning the advantages of an association with trawl vessels (Shane et al. 1986, Pace et al. 2003). Calves or subadult animals may also be more susceptible to bycatch due to curiosity or inexperience around fishing gear. For instance, bycaught harbor porpoises in German gill net fisheries were mainly subadults and weanlings (Siebert et al. 1996).

Patterns

There is much speculation as to why, when, and where marine mammals become captured in trawl gear. Information on marine mammal behaviors, foraging patterns, and distribution may play a crucial role in explaining the spatial and temporal occurrences of bycatch. Understanding the spatial and temporal patterns of bycatch is necessary to effectively mitigate the problem. Although many people believe that live, healthy marine mammals should be able to avoid capture in trawl nets, particularly when the nets are towed at slow speeds, previous research has shown that this is not always the case. Northridge (2003a) found bycaught common dolphins in bass pair trawl fishing gear were captured at the cod end of the net, many with their beaks poking through the mesh. The positioning of the animals suggested that they were actively swimming prior to capture and were alive when reaching the end of the net. Necropsy results indicated the animals had drowned, and muscle and ligament tears provided evidence that the animals struggled to escape (Northridge 2003a). Similarly, Lipscomb (1996) believes that marine mammals sustain traumatic injuries while struggling to free themselves from underwater entrapment. As the Northridge study indicates, it is likely that cetaceans are alive when caught, but they die due to drowning since the nets are not immediately retrieved after incidental capture occurs (Fertl and Leatherwood 1997).

In a study by Hartmann et al. (1996), researchers noted a dolphin became entangled by its tail at the front of a mid-water trawl net where the mesh size was large enough for a dolphin to swim through safely. The reason the animal became entangled is unknown. However, anecdotal reports suggest that an animal may have survived a similar entrapment at this location, implying the animal became caught during hauling of the net. Therefore, the animal was not underwater long enough for drowning to occur. The information of when the animal was caught may be helpful in explaining why the animal became entrapped. For instance, a change in the configuration of the net may have occurred during hauling.

Marine mammals may be particularly vulnerable to capture during certain phases in the trawl operation. When a trawl net is deployed, they may be captured due to proximity to a vessel. They may also enter the mouth of the net during towing but become captured when the boat slows or stops to haul in the catch (Fertl and Leatherwood 1997). Changes in speed or direction of a vessel may contribute to marine mammal bycatch since the size and shape of the net and its mouth may become altered, and the space for foraging animals to escape the net will become reduced or eliminated (SGFEN 2002). During trawling, the headline of the net creates a U-shape due to friction with surrounding water, creating spaces for marine mammals to become trapped (Northridge 1988). The shape of the headline and net may change significantly during different phases of fishing, including during hauling and during direction changes. Engines on trawl vessels produce characteristic sounds during stages of fishing which may be recognizable to cetaceans and attract the animals to feed during certain periods such as gear deployment or haulback (Leatherwood 1975, Fertl and Leatherwood 1997, Pace et al. 2003). Certain marine mammal behaviors may become associated with certain stages of trawl fishing.

Evidence suggests that species that forage in dense groups, such as common dolphins and pilot whales captured off the northeastern U.S. coast, may be particularly susceptible to capture in fishing gear (Waring et al. 1990, Fertl and Leatherwood 1997).

Morizur et al. (1999) found six of eighteen bycaught cetaceans were caught alone whereas the remaining twelve were caught in groups of between two and four individuals.

Where animals are found in the water column determines their likelihood of capture in trawl nets, with those foraging at mid-water depths highly vulnerable to mid-water trawls (Fertl and Leatherwood 1997). Mid-water trawls threaten marine mammals since they often target the same species, are large in size, and travel at relatively high speeds (Northridge 1988). Depths at which marine mammals are found may be closely correlated with the behaviors of prey species. Common dolphins which are caught in the *Loligo* squid fishery may follow the diurnal movement of the squid to the surface at night, causing the capture of common dolphins in the narrow fishing area at the top of the water column (Waring et al. 1990). During the day when fewer common dolphins are bycaught, the cetaceans may be spatially separated from their prey or deeper and more dispersed in the water column (Waring et al. 1990).

As indicated by common dolphins in the *Loligo* squid fishery, time of day may be an important component in understanding when the highest threat of marine mammal bycatch occurs in a fishery. However, bycatch occurrence differs between species and fisheries. For instance, common dolphin bycatch was highest at night for the squid and also the Atlantic mackerel fisheries in the northeastern United States between 1977 and 1988; however, for the Atlantic mackerel fishery, pilot whale bycatch occurred in a contrasting trend (Waring et al. 1990). More pilot whales were caught during the day than at night. Off of the Patagonian coast, the highest incidental takes of dusky dolphins in mid-water shrimp trawlers occurred at night (Dans et al. 1997, Crespo et al. 1997). In an experimental trawl fishery for tuna in the Northwest Atlantic, 22 of 29 takes that included pilot whales, bottlenose dolphins, risso dolphins, and a leatherback turtle occurred at night while the remaining 7 takes occurred in morning tows; however, it should be noted that the fishery, in general, towed at night (Goudey 1995). Similarly, all common dolphins and white-sided dolphins were captured at night or close to dawn in observed fisheries in the Northeast Atlantic, possibly due to an association between cetaceans and trawlers at night (Tregenza and Collet 1998, Morizur et al. 1999). Tregenza and Collet (1998) noted that 95% of the observed hauls occurred at night, with the exception of the hauls of Dutch vessels that occurred both at day and night. Maigret (1994) notes that dolphins may be caught at night since at this time, they are moving slowly near the surface, increasing the threat of capture.

Similar to time of day, seasonality may play an important role in identifying where overlap between marine mammals and trawlers will most likely lead to bycatch. Along the continental slope of southwest Ireland, cetacean catches in Dutch pelagic trawlers occurs in late winter and early spring when Atlantic white-sided dolphins move from offshore to inshore during their southward migration (Couperus 1997). Pilot whales in New England, U.S. were captured in trawl gear when their distribution concentrated along the southern shelf edge primarily between March and July while common dolphins were caught between December and February (Waring et al. 1990). For pinnipeds such as northern sea lions in the north Pacific and Bering Sea, the majority of bycatch occurred between late autumn and early spring when sea lions were not located on rookeries (Loughlin et al. 1983). Understanding the seasonal distribution of marine mammals may lead to identifying spatial and temporal overlaps with fisheries that may be modified to reduce incidental takes of these species.

Distribution may vary daily or seasonally as previously discussed, but it is also possible that males and females may exhibit differential selectivity in the habitat they utilize, making one sex more vulnerable to fishing gear (Crespo et al. 1997). It may be important to understand the sex ratio of bycaught animals to understand the impact of bycatch on cetacean populations. For instance, bycatch of Hooker's sea lions in New Zealand were predominately female (Slooten and Dawson 1995). Additionally, Dans et al. (1997) found 70% of bycaught dusky dolphins caught in the Patagonian shrimp fishery in the 1980's were females; half of these females were mature, and half of those animals were pregnant. Although the study size was small (n=23 animals), Dans et al. (1997) predicted that incidental mortality may have been high, particularly in 1984 through 1986, and the impact of the bycatch may have been severe since many of the bycaught animals were females of highest reproductive value. The shrimp trawl fishery is no longer in use off of Patagonia; however, experimental trawl nets are now used for southern anchovy, possibly continuing the threat of entanglement to the dusky dolphin population. In contrast to the bias towards the capture of female cetaceans observed by Dans et al. (1997), Morizur et al. (1999) noted all dolphins caught in four observed fisheries were adults of both sexes, highlighting the characteristic differences between fisheries and locations.

Bycatch Mitigation

For decades, bycatch was ignored in stock assessment reports and by managers, scientists, and environmentalists (Hall et al. 2000, Diamond 2004). Public awareness of dolphin bycatch in tuna fisheries, high bycatch of finfish in shrimp trawlers, and declines of fish stocks has increased pressure to manage for bycatch in U.S. fisheries (Hall et al. 2000, Diamond 2004). Today, many scientists, fishermen, and managers are working to identify, test, and implement methods to mitigate bycatch. Bycatch reduction strategies have generally focused on modifying fishing gear and practices and reducing the temporal and spatial overlap between fisheries and marine mammals, such as through time and/or area closures.

Due to differences between fisheries and species, bycatch mitigation measures will likely be fishery and location specific. A group of scientific experts on cetacean bycatch convened by the World Wildlife Fund in 2002 noted that "The most appropriate mitigation measures for each situation will depend on the nature and scope of the fishery, the species and behavior of the cetaceans involved and the financial resources available to address the problem (Read and Rosenberg 2002)." There have been a number of success stories in bycatch mitigation. Although some research suggests that knowledge from fishermen has been traditionally ignored in fisheries management and the conservation process (Macnab 1998, Bird et al. 2003), both fishermen and scientists have played important roles in these successes.

Gilman et al. (2005) noted that the knowledge and experience of fishermen can be tapped into to develop practical and effective solutions to mitigate bycatch. They also identified fishermen as some of the most qualified people to develop innovative strategies to address the problem of bycatch (Gilman et al. 2005). Rogers et al. (1997) indicated that fishermen have commonly made changes to gear, such as adding openings to nets, and to fishing practices. They have also moved to different fishing areas or reduced speed prior to hauling in an effort to reduce bycatch (Rogers et al. 1997). Some of these modifications to existing gear and fishing practices have been documented and formally tested.

One of the most widely known bycatch problems was solved in part through innovations of members of the fishing community. Dolphin bycatch in tuna purse seine fisheries in the eastern tropical Pacific Ocean is the best known case of marine mammal bycatch. Public awareness of this problem led to the creation of the Marine Mammal Protection Act in 1972 (Hall 1998, Hall et al. 2000). In this fishery, dolphins and tuna often travel together, and to capture tuna, fishermen encircle large herds of dolphins, a technique known as dolphin sets (Hall 1998). The number of dolphins caught in the net averaged group sizes of 400 to 500 individuals, although Hall (1998) noted it was not unusual to see groups of more than 1,000 dolphins captured in the gear. The species that are caught include spotted dolphin (*Stenella attenuata*), spinner dolphin (*S. longirostris*), common dolphin, and less commonly striped dolphin (*S. coeruleoalba*) (Hall 1998). Many of the mitigation measures to address this problem came from fishermen who felt public pressure to reduce dolphin bycatch (Hall et al. 2000). For instance, fishermen changed fishing practices by avoiding large groups of dolphins, decreasing sets around dolphins, and reducing sets with strong currents or at night (Hall et al. 2000). In addition, fishermen created a practice known as the backdown procedure which requires vessels to be placed in reverse after encircling a school of dolphins, allowing the net to be forced below the surface and providing an escape for captured dolphins (Northridge and Hofman 1999). To aid in the escape, the Medina panel, named after the fisherman who invented it, consists of a the replacement of mesh in the upper portions of the purse seine with a small-mesh netting which reduces the likelihood of entanglement when dolphins swim over the net during the backdown procedure (Northridge and Hofman 1999).

In addition to these modifications in gear and practices, fishermen also reduced dolphin bycatch in the tuna purse seine nets by adding a small raft into the process which allows fishermen to detect dolphins still in the net after the backdown procedure and to aid the dolphins in escape by hand using swimmers and divers (Gosliner 1999). These combined efforts designed by fishermen have resulted in a ninety-eight percent reduction in dolphin bycatch in this fishery since the problem was first discovered, making these the most effective bycatch solutions to date (Hall et al. 2000).

Although these solutions to the dolphin bycatch issue came from fishermen, scientists also played a role in addressing this conflict. Scientists played an important role in facilitating communication, identified the causes of high bycatch, assisted in testing ideas created by fishermen, and performed statistical analysis to test potential solutions (Hall et al. 2000).

Successful bycatch mitigation research has also come directly from the innovativeness of scientists. For instance, in another well known example of marine mammal bycatch, the capture of harbor porpoise in gillnets, scientific research led to effective bycatch reduction. Lien et al. (1995) hypothesized that harbor porpoise became entrapped in gillnets either due to a failure to detect the nets, an inability to classify the nets as barriers, or an attraction to fish swimming into or near the nets. These predictions about the nature of the interactions between harbor porpoise and gillnets led to the development of pingers, or acoustic devices, that emit a sound to indicate the presence of gillnets. It was originally believed that pingers operated by stimulating echolocation among harbor porpoise, allowing them to detect and avoid gillnets (Kraus et at. 1997). However, Cox et al. (2001) found that harbor porpoise actually echolocate less when in the presence of gillnets with pingers, and they direct their clicks away from the pingers. It is now believed that pingers may be effective since they displace animals from areas with gillnets (Culik et al. 2001).

In addition to pingers, times and areas with a high likelihood of harbor porpoise bycatch were identified through research into the spatial and temporal overlap between the animals and gillnets. By reducing the overlap between porpoise and fishing effort, time and area closures, along with pinger use, decreased harbor porpoise bycatch in gillnets from 2900 individuals in 1990 to 323 animals in 1999 (Read et al. 2006).

The bycatch reductions, which have been achieved in the tuna purse seine fishery and for harbor porpoise in gillnets, give hope for future bycatch mitigation efforts. Although there is no one solution that will work to reduce bycatch in all fisheries, many lessons can be learned from past experiences. Lessons from the eastern tropical Pacific tuna purse seine fishery demonstrate that reducing dolphin bycatch and maintaining the objectives of a fishery are not incompatible goals (Hall 1996). Bycatch can be successfully reduced without decreasing the economic viability or safety of a fishery. In addition, previous experience has demonstrated that fishermen should be involved in identifying and implementing mitigation measures. Not only do fishermen have knowledge, experience, and innovative ideas based on their years at sea, but they are also are more likely to support bycatch reduction strategies and regulations that they have a part in developing (St. Martin et al. 2007). Harbor porpoise bycatch in gillnets has demonstrated that, in some cases, reducing the overlap between marine mammals and fisheries temporally or spatially can effectively reduce bycatch. Even more potential may currently exist to modify trawl gear to reduce bycatch since it is actively fished in contrast with passive fishing gears, such as gillnets, which are set, left, and later retrieved (Read 2005). These past experiences give hope that successful bycatch mitigation can be identified for marine mammals in trawl fishing gear.

Bycatch Management

In some cases, bycatch mitigation can be implemented voluntarily by fishermen who wish to reduce bycatch or to improve public perception of their fishing operations; however, in most situations, a management framework is necessary to mandate changes in fishing practices to reduce bycatch. Management strategies that are effective at minimizing bycatch can be designed based on mitigation studies such as those previously discussed, but in most fisheries, studies to address bycatch occur in response to a need for management to address high bycatch. These studies can be time-consuming, and the results are not always easily interpreted or readily available. Bycatch can threaten critical marine mammal stocks, and sometimes quick action needs to be taken to reduce bycatch of these stocks. The National Oceanic and Atmospheric Administration (NOAA) is responsible for protecting the majority of marine mammal species in U.S. waters. NOAA is mandated under section 118 of the MMPA to create Take Reduction Teams (TRTs) in response to high bycatch of marine mammals in commercial fisheries that operate in U.S. waters. A TRT consists of fishermen and industry representatives, government employees, scientists, and environmentalists who are tasked with developing a take reduction plan to reduce bycatch of marine mammals in the fisheries being addressed. A TRT must reduce serious injury and mortality of marine mammal stocks in commercial fisheries below an allowed level, known as the Potential Biological Removal (PBR), within six months after it has been convened. A TRT was convened for marine mammal bycatch in Atlantic trawl fisheries in September 2006.

Most TRTs rely heavily on data from fishery observers to design take reduction plans. Trained fishery observers in the United States collect and process data and biological samples while at sea aboard working commercial vessels. Due to federal protections afforded to marine mammals, sea turtles, and some sea birds under the MMPA and the Endangered Species Act (ESA), fishery observers monitor the number of these animals seriously injured or killed by commercial fishing operations.

Fishery observers attempt to record serious injury and mortality of all marine mammals and other protected species in fishing gear, but bycatch is considered a rare event, that is, one in which observed sets or hauls of fishing gear often yield no bycatch and only rarely result in bycatch of marine mammals. King and Zeng (2001) defined rare events data as binary data that have extremely fewer "ones", or occurrences, than "zeros." Rare event data does not need to be binary in nature. For instance, bycatch may occur of one, two, or more animals. It is considered a rare event when the occurrence of bycatch of one or more individuals in a fishing haul occurs far less frequently than fishing hauls that do not result in bycatch. Bycatch may be a rare event in many fisheries since its occurrence is extremely infrequent or because cetaceans may be absent from areas covered by fishing gear (Hilborn and Mangel 1997). It is also possible that bycatch is rare when compared to intense fishing effort in a fishery or area. Furthermore, bycatch may appear rare due to low observer coverage in a fishery.

Regardless of the cause of rare bycatch, the infrequency of the events presents a challenge for analyzing bycatch data and identifying spatial and temporal or operational patterns to them, which are necessary for determining appropriate measures to mitigate bycatch. The rarity of species or events introduces difficulties in estimating abundance and modeling distribution. Datasets with too many zeros, or sets or hauls of fishing gear with no bycatch, than are estimated by standard distributions may yield invalid models (Mayer et al. 2005). Furthermore, Martin et al. (2005) explain that inference will be incorrect unless analyses consider how excess zeros arose in a dataset. The large number of zeros in a dataset will also violate assumptions of a model, such as that of constant error variance (Fletcher et al. 2005, Martin et al. 2005, Mayer et al. 2005). These problems that arise from rare events data, such as bycatch, will lead to inaccurate models on which to base bycatch management.

Much of the observer data on which most TRTs base their decisions for managing bycatch is based on data that is sparse due to the rarity of bycatch or of fishery observations. To improve the availability of data for TRTs, the knowledge of fishermen needs to be included in the process. Although TRTs are designed to be a collaborative process by including diverse stakeholder groups, little information is currently exchanged within this management framework. However, fishermen have years of experience at sea, and their contributions can lead to not only more appropriate management strategies but also ones that will be supported by the fishing industry (St. Martin et al. 2007). Fishermen's knowledge provides long-term information about local fishing areas, distribution, and harvest patterns (St. Martin 2001, Moller et al. 2004, Aswani and Lauer 2006, Close and Hall 2006, Hall and Close 2007). Fishermen also notice changes in their environment over time (Hall and Pederson 1999, Moller et al. 2004, Grant and Berkes 2007, Hall and Close 2007), and they know how to respond to these changes (Moller et al. 2004). This information can help to identify adaptive management measures. Furthermore, this knowledge can complement information obtained through fishery observers, which in contrast to fishermen's knowledge usually offers short-term observations over a larger spatial scale due to the difficulty and expense of collecting this data (Moller et al. 2004).

As previously discussed, fishermen have also played a fundamental role in identifying ways to reduce bycatch. As Rogers et al. (1997) explain, fishermen have commonly made changes to fishing gear to mitigate interactions with marine mammals. Fishermen's innovativeness also contributed to a ninety-eight percent reduction in dolphin bycatch in the eastern tropical Pacific tuna fishery since the bycatch problem was first discovered in this fishery (Hall et al. 2000). Thus, by including fishermen's knowledge into the TRT process, the teams can better understand patterns of bycatch and can develop more effective strategies to mitigate the interactions.

This study focuses on understanding the spatial and temporal patterns associated with cetacean bycatch in the New England bottom trawl fishery for groundfish to aid in the development of an effective take reduction plan. Using the lessons learned from previous experiences, this study focuses on combining the knowledge of fishermen with fishery observations to provide a better understanding of these interactions. The goal of this research is to identify potential mitigation measures that will be both effective and supported by the fishing industry. Methodology created to combine disparate data sources can be applied to other human-marine mammal interactions; thus, this study has the potential to have widespread and significant impacts on the conservation of marine mammal populations which are impacted globally by bycatch.

CHAPTER II

MODELING BYCATCH OF ATLANTIC WHITE-SIDED DOLPHINS IN THE NORTHWEST ATLANTIC BOTTOM TRAWL FISHERY USING FISHERY OBSERVATIONS

Introduction

Bycatch, or unintentional capture, of marine mammals occurs worldwide and in nearly every type of fishing gear. In the United States, trained observers collect and process data and biological samples while at sea aboard working commercial fishing vessels. Due to federal protections afforded to marine mammals, sea turtles, and some sea birds under the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA), fishery observers collect information that pertains to interactions between these animals and commercial fishing operations. The observer programs monitor the number of animals taken in several fisheries. Defined by the MMPA and with a similar meaning under the ESA, the term "take" means "to harass, hunt, capture, kill, collect, or attempt to harass, hunt, capture, kill, or collect" any protected animal. The number of marine mammals taken in a particular fishery based on the observations of fishery observers can be used to estimate the amount of bycatch of each species in the entire fishery (NMFS 2004). These bycatch estimates assume that observer coverage is representative of overall fishing behaviors, meaning fishermen do not change their fishing practices or locations while an observer is onboard.

Based on data collected by fishery observers, the number of cetaceans bycaught in trawl fishing gear in the western Atlantic Ocean along the United States' East Coast has garnered attention in recent years. In 2003, the Center for Biological Diversity sued the National Marine Fisheries Service (NMFS) for failure to address bycatch of pilot whales (*Globicephala mela*) and common dolphins (*Delphinus delphis*) in the U.S. east coast Squid/Mackerel/Butterfish trawl fishery (TRT 2007). In 2006, as part of the settlement agreement, the NMFS convened the Atlantic Trawl Gear Take Reduction Team (ATGTRT) under section 118 of the MMPA. The MMPA protects all marine mammals in United States' waters. Section 118 of the MMPA specifically addresses the taking of marine mammals by commercial fishing operations. This section allows the Secretary of Commerce to implement a team of representatives, known as the take reduction team (TRT), to develop a take reduction plan to reduce mortality or serious injury of a marine mammal stock in commercial fishing operations. Although the settlement agreement required the NMFS to address bycatch of pilot whales and common dolphins, the NMFS expanded the TRT to also cover Atlantic white-sided dolphins (*Lagenorhynchus acutus*) and all east coast trawl fisheries. One of these fisheries and the one that will be the focus of this paper is the U.S. Northeast bottom trawl fishery for groundfish.

The bottom trawl fishery for groundfish operates in waters from Nova Scotia to Cape Hatteras, North Carolina. This research will focus on the portion of the fishery that operates in the U.S. Northeast off of New England, including the Gulf of Maine and Georges Bank. Bottom trawlers who operate in this area are part of the Northeast multispecies fishery, which is managed by the New England Fishery Management Council. Some of the groundfish species caught by this fishery and managed by the

Council include American plaice (*Hippoglossoides platessoides*); Atlantic cod (*Gadus morhua*); Atlantic halibut (*Hippoglossus hippoglossus*); haddock (*Melanogrammus aeglefinus*); ocean pout (*Zoarces americanus*); offshore (*Merluccius albidus*), red (*Urophycis chuss*), silver (*Merluccius bilinearis*), and white (*Urophycis tenuis*) hake; pollock (*Pollachius virens*); redfish (*Sebastes fasciatus*); and windowpane (*Scophthalmus aquosus*), winter (*Pseudopleuronectes americanus*), witch (*Glyptocephalus cynoglossus*), and yellowtail (*Limanda ferruginea*) flounder. The multi-species characteristic of this fishery is due in part to the non-selective nature of the fishing gear and in part due to the biological co-occurrence of these species in the Gulf of Maine and on Georges Bank (Murawski et al. 1983). Market demand for fish species also plays an important role in which species are caught and landed.

Previous research has indicated that major fishing areas utilized by the Northeast bottom trawl fishery include the near-shore and deep water areas of the Gulf of Maine and the shallow and edge portions of Georges Bank based on analyses of fisheries catch data of multiple groundfish species (Murawski et al. 1983). Although fish species composition and abundance have changed since this research was conducted, these areas of the Gulf of Maine and Georges Bank remain some of the most productive fishing areas near New England and key areas for commercial fishing operations (Wiebe et al. 2002). This productivity results from the topographic and oceanographic conditions, particularly on Georges Bank, that support an abundance of phytoplankton and zooplankton (Wiebe et al. 2002).

Georges Bank is an extension of the continental shelf and forms the southern boundary of the Gulf of Maine. Generally, the northern portion of Georges Bank is characterized by cool waters, influenced by the neighboring deep and cold Gulf of Maine, while the southern portion is warmer, influenced instead by the Gulf Stream (Murawski and Finn 1988). Water in the Gulf of Maine and on Georges Bank originates from cold, low saline water that moves southward along the surface from the Scotian Shelf. This water mixes with warmer and more saline water that moves westward at deep depths from the Northeast Channel and into Georges Basin (Wiebe et al. 2002). As this water mixes and moves in a counterclockwise gyre throughout the Gulf of Maine and onto the northern portion of Georges Bank, it brings nutrients from deep depths back to the surface where light is available and primary productivity can occur. Meanwhile, water from the South enters Georges Bank and rotates in a clockwise gyre. Where tidal mixing occurs in the center portion of the Bank, warm water meets nutrients from upwelling regions and creates an area of high productivity (Wiebe et al. 2002).

Oceanographic and topographic conditions of Georges Bank and the Gulf of Maine do vary between seasons and from year to year; thus, catch of groundfish species is also variable by year, season, and location (Murawski et al. 1983, Murawski and Finn 1988). For instance, the bottom temperature of Georges Bank at various depths is variable. The temperature ranges up to 15 degrees C in shallow regions (<100m) (Murawski and Finn 1988). However, at greater depths, specifically those greater than 250m, the range in bottom temperature is much smaller. Some groundfish species have demonstrated preferences in bottom temperature and/or depth. For instance, silver and red hakes are found in a narrow range of bottom temperature and at various depths while Atlantic cod and flounders, including yellowtail and winter, were captured in a wider range of bottom temperatures and a narrower range of depths (Murawski and Finn 1988).

Species that are primarily affected by temperature fluctuations are more likely to exhibit seasonal and interannual variability in distribution than species most influenced by depth. This variability is also seen in groundfish catches of the Northeast bottom trawl fishery.

In the Northeast bottom trawl fishery, several cetacean species are captured as bycatch, including common dolphins, pilot whales, harbour porpoise (*Phocoena phocoena*), minke whales (*Balaenoptera acutorostrata*), and Risso's dolphins (*Grampus griseus*). However, the observer program data indicates that the species most often caught by this fishery is the Atlantic white-sided dolphin (TRT 2007).

Three stocks of Atlantic white-sided dolphins are believed to exist in the western North Atlantic Ocean including the Gulf of Maine, Gulf of St. Lawrence, and Labrador Sea stocks (Palka et al. 1997). The Gulf of Maine stock commonly occurs in the Gulf of Maine and lower Bay of Fundy in addition to on the continental shelf in waters from the Hudson Canyon north to Georges Bank (NOAA 2005). The best estimate of abundance of the Gulf of Maine stock of Atlantic white-sided dolphins has recently been updated from 51,640 (NOAA 2005) to 63,368 individuals (NOAA 2007). This stock is found over the continental shelf and slope in deep oceanic waters (Cipriano 2002). Atlantic white-sided dolphins prefer colder and less saline waters than common dolphins, and they exhibit seasonal distribution shifts, possibly due to changes in the distribution of prey species (Selzer and Payne 1988). In the winter and spring, the species is commonly found in the southwestern waters of the Gulf of Maine, in the Great South Channel, and on Georges Bank (Selzer and Payne 1988, Northridge et al. 1997), where their occurrence coincides with a seasonal peak in abundance of an important prey species, sand lance (*Ammodytes americanus*) (Meyer et al. 1979, Kenney and Winn 1986). In the summer and fall, Atlantic white-sided dolphins are more evenly spread throughout the Gulf of Maine (Selzer and Payne 1988, Northridge et al. 1997), during a period in which sand lance availability is decreased due to spawning (Meyer et al. 1979). Year round, there have been sightings of Atlantic-white sided dolphins South of Georges Bank but always at low densities. Throughout the year, this stock of Atlantic white-sided dolphins commonly encounters fishing activities in the Northwest Atlantic Ocean.

The Gulf of Maine stock of Atlantic white-sided dolphins and all other marine mammals in United States' waters are protected by the MMPA. The MMPA sets a potential biological removal (PBR) level for each marine mammal population, which is based on the maximum number of individuals that can be removed from a stock from non-natural causes while still allowing it to obtain maximum productivity. The MMPA defines PBR as the product between the stock's minimum population estimate, one half of its maximum net productivity rate, and a recovery factory between 0.1 and 1 set based on best scientific judgment. According to the MMPA, bycatch of marine mammals should not exceed PBR and should approach zero mortality. Stocks where PBR is exceeded are considered "strategic." Amendments to section 118 of the MMPA in 1994 established the zero mortality rate goal by stating that "commercial fisheries shall reduce incidental mortality and serious injury to marine mammals to insignificant levels approaching a zero mortality and serious injury rate (MMPA, p.61)." The zero mortality goal was later defined by NMFS in regulation as ten percent of PBR.

Based on data from 2000 to 2004, bycatch of Atlantic white-sided dolphins is estimated at a mean annual mortality of 197 animals, with 130 of those estimated to be caught in Northeast bottom trawls (TRT 2006). Bycatch of the Gulf of Maine stock of

Atlantic white-sided dolphins occurs in other U.S. fisheries, including a mean annual mortality estimate of 24 in Northeast sink gillnets, 25 in Mid-Atlantic bottom trawls, 1 in Northeast mid-water single and pair trawls, 15 in Mid-Atlantic mid-water single and pair trawls, and 2 in joint venture Gulf of Maine and Georges Bank herring trawls (TRT 2006).

Estimated bycatch in U.S. Northeast sink gillnets was highest in 1992, 1993, and 1994, at 154, 205, and 240 animals respectively, but decreased in subsequent years (TRT 2006). This decrease likely resulted from the implementation of bycatch mitigation measures, including time and area closures and acoustic devices, designed to reduce harbour porpoise bycatch in gillnets (Read et al. 2006).

In addition to estimates from observers aboard U.S. fishing vessels, bycatch also likely occurs on Canadian fishing vessels, although little information about these fisheries is available (NOAA 2005). The number of bycaught animals is believed to be much smaller than in U.S. fisheries. For instance, between 1991 and 1996, only six animals were estimated to be taken in Canadian fisheries (NOAA 2005).

Although once considered strategic in 1995 (Blaylock et al. 1995 as cited in Palka et al. 1997), today the bycatch of Atlantic white-sided dolphins does not exceed PBR of 509 individuals (TRT 2007). However, bycatch of Atlantic white-sided dolphins does surpass the zero mortality goal. In 2005, there were 118 observed takes of Atlantic white-sided dolphins in the Northeast bottom trawl fishery alone (Fred Wenzel, pers. comm., September 2006). This count includes dolphins of all conditions, including those that were moderately or severely decomposed, which suggests that some of these animals were already dead when picked up by the trawl net. However, it is known that bycatch of

Atlantic white-sided dolphins occurs and has exceeded PBR in the past; thus, it is in the best interest of fishermen and managers to address future bycatch before it becomes a threat to this stock.

The ATGTRT, which was implemented to address bycatch while its incidence was below PBR, presents fishermen, scientists, and managers with a unique opportunity to cooperatively develop effective, precautionary measures to keep bycatch below PBR and to approach zero mortality. This study aims to understand spatial and temporal patterns associated with Atlantic white-sided dolphin bycatch in the Northeast bottom trawl fishery and to aid in the development of bycatch mitigation strategies.

In order to identify the areas with the highest probability of bycatch for Atlantic white-sided dolphins in the Northeast bottom trawl fishery, the observations of bycatch will be related to environmental and fishing characteristics. There are numerous approaches for analyzing datasets such as the observer program observations of bycatch. For instance, generalized linear models (GLMs) are often used to relate the presence or absence of a species or event to existing environmental conditions. A GLM upholds the assumption of linearity by accounting for non-linearity through the use of a link function between the response and predictor variables (Guisan et al. 2002, Redfern et al. 2006). This flexibility allows GLMs to be used in analyzing data that describe ecological relationships. For instance, Canadas et al. (2005) used a GLM to describe the relationship between several cetacean species and their preferred habitat characteristics. Murray (2004) used a GLM to identify environmental factors that influenced sea turtle bycatch rates in a scallop dredge fishery.

Since GLMs are not assumed to follow normality, the response variable can follow any number of alternative distributions. Bycatch data often follows a Poisson distribution since it can be analyzed as count data but the likelihood of a large number of events (caught animals) is rare (Redfern et al. 2006). For instance, a haul of fishing gear can have zero, one, two, three, etc… number of bycaught marine mammals. However, a Poisson distribution assumes that the mean and variance are equal since it has one free parameter (Zar 1996). Thus, the variance cannot change independently of the mean. When this assumption is violated, over-dispersion occurs, and an alternative to the GLM with a Poisson distribution must be used.

There are several models that take over-dispersion into account, or that assume that the variance is greater than or equal to the sample mean. For instance, Sullivan et al. (2006) considered a quasi-Poisson and a negative binomial distribution to test the differences between several seabird bycatch mitigation measures by looking at the number of times a seabird came into contact with trawl gear related to observation time and environmental variables. Both the quasi-Poisson distribution and the negative binomial distribution can handle over-dispersed data. Sullivan et al. (2006) chose the negative binomial distribution for modeling seabird bycatch. Hilborn and Mangel (1997) also suggest a negative binomial for analyzing bycatch data in which no bycatch is a common occurrence and high levels of bycatch are rare. Gonzalez-Zevallos et al. (2007) used a quasi-Poisson distribution to model the number of seabird contacts with trawl gear and recorded variables including wind speed and ambient temperature.

Models such as the negative binomial and quasi-Poisson model account for over-dispersion, which is often encountered in ecological datasets such as studies of bycatch;

however, these models cannot account for zeros in excess of what is expected by the distribution (Cunningham and Lindenmayer 2005, Martin et al. 2005). Fletcher et al. (2005) point out that excess zeros may result due to patchiness of the environment as well as due to inherent differences of the species. In an example provided by Stefansson (1996), an excess of zeros occurs when data on groundfish species from a fishery haul are split into age groups and certain age classes are missing from the haul.

Cunningham and Lindenmayer (2005) indicate that zero-inflated data can also arise from datasets for uncommon or rare species or events. Rare events data have been defined as having extremely fewer "ones", or occurrences, than "zeros" (King and Zeng 2001). Rare event data does not need to be binary in nature. For instance, bycatch may occur of one, two, or more animals. It is considered a rare event when the occurrence of bycatch of one or more individuals in a fishing haul occurs far less frequently than fishing hauls that do not result in bycatch. These types of datasets are common in political and social sciences, including for events such as wars, coups, or uncommon diseases (King and Zeng 2001), and as previously mentioned, they are also encountered in ecological datasets such as bycatch data. Bycatch may be a rare event in many fisheries since its occurrence is extremely infrequent or because cetaceans may be absent from areas covered by fishing gear (Hilborn and Mangel 1997). Thus, there will likely be many hauls with no bycatch and a few hauls with one, two, three, etc… captured animals.

From a statistical perspective, rare populations or events are those with a low number of individuals or occurrences (McDonald 2004). Populations or events that are common may also be considered rare when they are unable to be detected such as because of ineffective survey techniques, sparse distributions over large areas, or elusive behaviors (McDonald 2004). Elusive behaviors include those in which animals are secretive, noctural, or underwater (McDonald 2004), the latter of which is often a problem when studying marine mammals. The rarity of species or events introduces difficulties in estimating abundance and modeling distribution. Logistic regression has been used successfully for modeling rare events or populations based on the presence or absence of species, such as for spotted owls, salamanders, chipmunks, and koalas (see McDonald 2004); however, it can underestimate the probability of a rare event (King and Zeng 2001).

When datasets contain many zero values (i.e. hauls with no bycatch), they often do not fit into standard distributions, such as normal, Poisson, binomial, negative binomial, and others (Stefansson 1996, Martin et al. 2005). As the number of zeros in a dataset increases, these standard distributions become less valid (Mayer et al. 2005); they assume that the proportion of zero values come from the same distribution as the positive values (Fletcher et al. 2005). Minami et al. (2007) found that a negative binomial distribution overestimated model coefficients when it was used to model data with excess zeros.

When excess zeros arise in a dataset, they are important to take into account for several additional reasons. Martin et al. (2005) explain that inference will be incorrect unless analyses consider how excess zeros arose in a dataset. Inflated numbers of zeros will also violate assumptions, such as of constant error variance (Fletcher et al. 2005, Martin et al. 2005, Mayer et al. 2005). Transformations which are often used in ecology to normalize the distribution of positive values in datasets will not be able to spread out the excess of zero values and will instead result in an inflated number of the value to which the zeros are transformed (Martin et al. 2005).

In order to account for the inflation of zeros in datasets such as those with rare bycatch events, two types of models are suggested. The first is a conditional or two-part model. These models approach a dataset with excess zeros in two stages. First, a binomial distribution is used to represent the portion of the dataset with zeros and ones to model the presence or absence of a sighting or bycatch incident (Stefansson 1996, Mayer et al. 2005). Next, the positive values of a dataset are modeled (Stefansson 1996, Cunningham and Lindenmayer 2005, Mayer et al. 2005). Thus, they are called conditional models since they are conditional upon the presence of an animal or an event. As in other ecological applications, researchers have often used the Poisson or negative binomial distribution for this second model (Mayer et al. 2005); however, other distributions are possible including the gamma and log-Normal distributions (Stefansson 1996, Mayer et al. 2005, Fletcher et al. 2005).

Conditional models have been used for a number of marine datasets with inflated counts of zeros. For instance, Stefansson (1996) used a two-part, conditional model to model groundfish survey data. As previously mentioned, the excess zeros in Stefansson's dataset resulted from missing groundfish age classes in fishing hauls. Fletcher et al. (2005) used a conditional model to investigate the relationship between algal and sea urchin (*Evechinus chloroticus*) abundance within a study site in New Zealand and to make predictions that could be used for management decisions. The excess zeros in this second study resulted from the absence of the algae at sampling sites.

The problem with using conditional models is that they often overestimate zeros (Mayer et al. 2005). They do this because the second part of the process, which only uses data with positive values greater than zero, also predicts a number of zeros. When these predicted zeros are added to the zeros used in the first part of the model, an overestimation of zeros occurs. One way to overcome this limitation is to use truncated models which truncate the distribution at a value greater than zero, such as one in count data (Andy Cooper, pers. comm., March 15, 2007). Mayer et al. (2005) found a truncated log-Normal distribution for the second part of a two-part model gave the best predictive results of fish species in estuaries of Australia. Mayer et al. (2005) noted the difficulties in using these truncated models which have yet to be incorporated into the most commonly used statistical packages; thus, complex coding is required to use these procedures.

The second type of model that deals with an inflation of zeros in datasets is a type of mixture model, namely zero-inflated models. Zero-inflated models consider data in two states, the 'perfect state' which only considers zero, or no bycatch, values and the 'imperfect state' which considers both zero and non-zero values (Minami et al. 2007). These models are a type of mixture model since they combine two distributions. For instance, a zero-inflated Poisson mixture model can take the excess zeros into account for the count data that follows a Poisson distribution (Martin et al. 2005). Compared to conditional models which assume that zeros arise from one process and a set of covariates, a zero-inflated mixture model allows zeros to arise from either process and the related covariates (Martin et al. 2005).

Although relatively new, zero-inflated models have found some utility in ecological data and can be appropriate for modeling bycatch data. Martin et al. (2005) found that the zero-inflated Poisson (ZIP) and the zero-inflated negative binomial (ZINB) performed better than the standard Poisson distribution in modeling habitat for three woodland bird species. Results of this study indicated that failing to account for excess zeros that arise in datasets can lead to incorrect parameter and precision estimates in models (Martin et al. 2005). Minami et al. (2007) reported that zero-inflated models are appropriate for catch data of species with a rare probability of capture or encounter. Further, they found these types of models appropriate when the causes related to the capture of a species are poorly understood. Minami et al. (2007) suggested a zero-inflated mixture model could be used for modeling data where species are caught infrequently; a ZIP model would be chosen for species that when present occur in small groups and a ZINB for those species that occur in large groups when present. Based on these criteria, a ZINB was chosen for modeling shark bycatch in the eastern tropical Pacific tuna purse-seine fishery (Minami et al. 2007).

Despite the increasing awareness of the utility of zero-inflated mixture models, there are still drawbacks to this approach. The first is that they still have not been incorporated into most statistical packages, meaning that more complicated software packages such as WinBUGs must be used (Martin et al. 2005). Zero-inflated mixture models, compared to conditional models, allow zeros to be included in both the perfect and imperfect condition. This is one of the main differences between the two types of models which actually allows the zero-inflated model to provide a better fit for data when zeros arise due to measurement error (Fletcher et al. 2005). Zero-inflated models are also less likely to overestimate zeros. However, there is an associated disadvantage that results in zero-inflated models being more difficult to interpret and estimation being less straightforward than conditional models (Cunningham and Lindenmayer 2005, Fletcher et al. 2005, Martin et al. 2005). Conditional model analysis is simpler as the two-part modeling approach allows for the parameters to be estimated and interpreted independently (Cunningham and Lindenmayer 2005, Fletcher et al. 2005). Finally, the conditional model allows researchers to model the zero values and positive abundances separately so that they can discern how they each are being impacted by the covariates (Fletcher et al. 2005). In other words, conditional models make it possible to identify separate factors that explain presence or absence of occurrences from those that predict abundance (Cunningham and Lindenmayer 2005).

Models that find a relationship between the occurrence of a species and associated characteristics of the environment operate under several assumptions. First of all, the models assume that the species have been correctly identified (Canadas et al. 2005). They also assume that the chosen environmental variables are in fact the correctly identified predictors of habitat preference (Canadas et al. 2005), and that these environmental variables are the primary determinants influencing the distribution of a species (Latimer at al. 2006). The environmental variables are assumed to be constant throughout the timeframe of the study (Canadas et al. 2005). Predictive models also assume that species have reached or have nearly reached equilibrium with the chosen environmental characteristics, meaning that the species actually use the habitat where they were sighted or captured and that they were not simply traveling through that habitat when the study occurred (Guisan et al. 2002, Latimer et al. 2006). Canadas et al. (2005)

also explain that predictive models assume that habitats are correctly classified as being used or not used, that animals can access all habitats but are found in the habitats they use, and that the probability of locating an animal throughout the area surveyed is equal. If any of these model assumptions are violated, Latimer et al. (2006) point out that the models may not provide enough power to predict habitat or bycatch locations, or they may underestimate uncertainty when making predictions. Both of these outcomes may also result when there is insufficient data to make accurate predictions (Latimer et al. 2006).

One assumption of GLMs that is often violated by ecological data is the assumption that the values of the response variable, in this case bycatch events, are independent of one another (Zar 1996, Redfern et al. 2006). Violations of this assumption occur when data are spatially or temporally autocorrelated. For instance, spatial dependence occurs when correlation among observations depends on their relative locations (Latimer et al. 2006). It is typical in ecological datasets for positive autocorrelation to exist since pairs of observations that are found near one another typically are more similar than observations that are farther apart (Latimer et al. 2006). Biological processes such as animals interacting with one another or with their environment and behaviors including reproduction, territoriality, and dispersal often generate spatial or temporal patterns (Latimer et al. 2006). Thus, it is likely that bycatch data will have spatial or temporal autocorrelation.

Models that include all the variables that influence the habitat choice or bycatch incidents will not have spatial or temporal autocorrelation. Spatial or temporal autocorrelation of events occurs in a model when the variable or variables responsible for the dependence is not taken into consideration. The variable may be an environmental characteristic that was not included in the model, or it can be unrelated to habitat preference, such as social behavior (Canadas et al. 2005) or one of the other biological processes mentioned above. When autocorrelation exists, it will be evident in the error residuals; thus, the assumption that errors are independently distributed will also be violated.

If this dependence between sightings or bycatch events is not taken into account, incorrect predictions in habitat or bycatch distribution may occur, and the model will falsely identify environmental characteristics as significant predictors of distribution (Canadas et al. 2005). It is likely that more predictor variables will be seen as significantly related to the presence or absence of a bycatch event or animal sighting (Latimer et al. 2006). Furthermore, when models ignore this relationship between observations, inaccurate parameter estimates result as do insufficient estimates of uncertainty (Latimer et al. 2006).

Thus, by taking spatial or temporal autocorrelation into account, the predictive power of models is increased. Spatial autocorrelation can be incorporated into regression or generalized linear models through the addition of random effects that explain that spatial dependence in the data (Latimer et al. 2006). The spatial random effects in these models will take spatial autocorrelation into account, reduce uncertainty in parameter estimates, and uphold the assumption that all observations are independent of one another (Latimer et al. 2006, Redfern et al. 2006).

Methods

Data

Observer program data from the Northeast Fishery Observer Program (NEFOP), managed by the Fisheries Sampling Branch of the Northeast Fisheries Science Center, was obtained from 1996 through 2005 for the Northeast multispecies fishery. The percent of observer coverage in the fishery fluctuated during this time period due to funding, weather, and other factors. For instance, the observer coverage typically varied from 0.1 to 0.4 percent of trips between 1996 and 2000 and from one to five percent of trips between 2001 and 2004 (NOAA 2002, 2007). In 2005, the observer coverage increased to twelve percent (NOAA 2007).

Bycatch records that were analyzed were isolated to Atlantic white-sided dolphins, and then further reduced to include only those animals that were alive or classified as freshly dead. Animals that were classified by the NEFOP as moderately or severely decomposed were not considered in this analysis. This decision was made since it cannot be determined and is unlikely that the moderately and severely decomposed animals were killed in the bottom trawl gear in which they were observed and in the location associated with the observer program records. This decision is also consistent with the practices of the NMFS (Debi Palka, pers. comm., June 7, 2007).

The study area was defined as the Gulf of Maine and Georges Bank. Fishing effort and bycatch events that were included in the analysis were limited to the region between 39°48' and 44°54' North latitude and -71°6' and -66°15' West longitude (Figure 1). These coordinates were selected to incorporate areas fished by the New England bottom trawl fishery or areas where fishing may be directed in the future. A map of the

Study Area

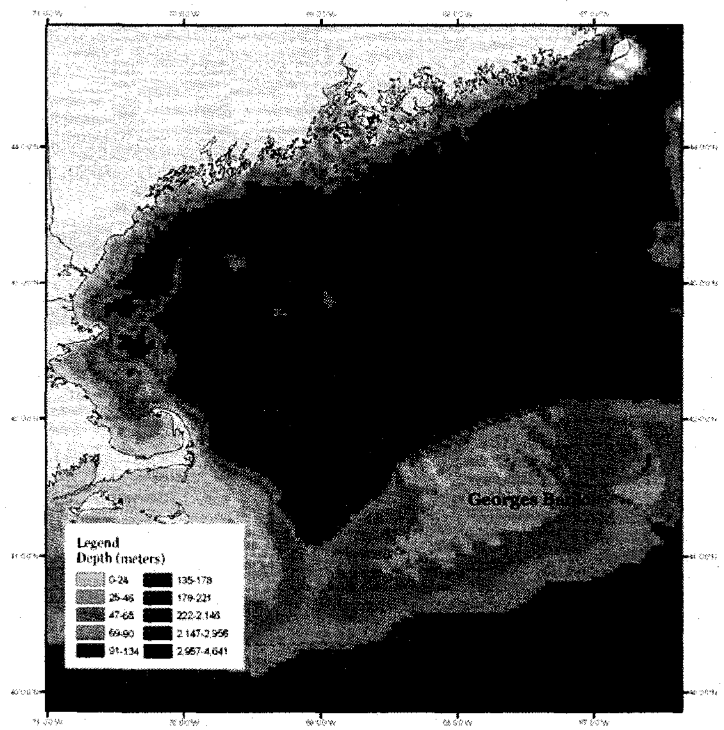

Figure 1. The study area consists of fishing areas in the Gulf of Maine and on Georges Bank.

locations of all observed hauls from 1996 through 2005 was used to choose the latitude and longitude coordinates that would define the study area. Based on the map, southern coordinates were selected where a differentiation in fishing patterns was noticeable. North of these selected coordinates, fishing effort patterns were consistent with fishing patterns of the Northeast bottom trawl fishery in terms of perceived bottom type and depth while south of the selected coordinates, fishing patterns were more similar to fishing patterns of the Mid-Atlantic trawl fishery. The Mid-Atlantic trawl fishery operates along the continental shelf edge. The western coordinates were chosen at the state border between Massachusetts and Rhode Island, also based on fishing patterns and the delineation between the New England and Mid-Atlantic fisheries.

The observer program data was arranged by haul. The haul is defined as when and where the trawl tow ended and the net and its catch were hauled from the water. The observer program records indicated whether each haul resulted in a bycatch incident or not. Environmental characteristics that most closely aligned with the date and latitude and longitudinal coordinates of the haul were matched which each haul record. It was assumed that the conditions at the haul were the same as those throughout the trawl. In other words, if bycatch occurred during the trawl, the environmental conditions recorded at the time of the haul were assumed to be the same as when the bycatch event occurred. The environmental conditions considered in this study include:

Depth. Depth was recorded by fishery observers at the beginning of each haul. It was assumed that the depth at the beginning of a haul did not change significantly from depth at the end of a haul. Depth was recorded in fathoms but converted into meters for analysis.

Bottom slope. Bottom slope was obtained from a raster map developed by Chris Orphanides at the NMFS using the ArcMap 8.3 Spatial Analyst slope function and a depth dataset, ETOPO Global 2' Elevations, from the National Geophysical Data Center. The ETOPO dataset provides depth in meters based on a 2-minute spatial resolution; therefore, fluctuations in bottom topography smaller than this spatial scale will not be reflected in this dataset. Bottom slope, measured in degrees, describes the rate of change in depth of the cells surrounding the cell being operated on (Chris Orphanides, pers. comm., January 2007).

Sea surface temperature (SST). Data from two sea surface temperature datasets were utilized, including from overlapping five-day SST composites and from non-overlapping 5-day climatology images for each consecutive 5-day period. The former included data from four satellites: AVHRR Pathfinder Version 5, Modis Aqua, Modis Terra, and the GOES satellites. The five day composites consisted of data from the day of the haul and two days prior and two days after the haul. Data was used from whichever satellite were available for a given day in order to maximize data accuracy and to minimize data gaps due to cloud cover. On days when all satellites provided data, separate composites were made, and aggressive cloud masks were applied to exclude cloudy pixels. Climatology images used were from NASA's Jet Propulsion Laboratory based on non-overlapping 5-day periods beginning on the first of the year.

SST was matched to each haul in the observer program data. Both sources of data were sampled by Chris Orphanides using a custom program written in ArcGIS. SST corresponding to the haul latitude and longitude point data was selected when available; otherwise, median SST of a surrounding 3 by 3 cell area was estimated when no valid data could be retrieved for a point location. A hierarchy of data sources was used when selecting the final SST value: point data was selected before a median estimate and overlapping five-day SST composites were used before climatology data. To ensure no anomalies were included in the data analysis, a program was run that compared the overlapping five-day SST composites with the climatology data. When a difference was found to be greater than 2.5 degrees Celsius, the climatology data was used (Chris Orphanides, pers. comm., January 2007). SST is measured in degrees Celsius.

Chlorophyll. Chlorophyll data first became available in September 1997 so hauls prior to this date were not associated with chlorophyll values. From September 1997 until July 2002, 5-day chlorophyll composites were used that were created from single day chlorophyll a Standard Mapped Images (SMIs) (Chris Orphanides, pers. comm., September 2007). These composites were created with a 9 kilometer resolution using geometric means. From July 2002 through 2005, the composites were created using MODIS Aqua SMIs (4 kilometer resolution) and SeaWiFS level 3 SMIs (9 kilometer resolution) (Chris Orphanides, pers. comm., September 2007). These composites from the two sources were then combined into one five day composite. Since MODIS data had a finer resolution, it was used first, and the SeaWiFS data was resampled to a 4 kilometer scale and then used to fill in missing values when necessary.

A chlorophyll value was matched with a point location associated with a haul when data was available (Chris Orphanides, pers. comm., September 2007). When a point value was unavailable, a mean for the surrounding area of approximately 12 kilometers (3 by 3 cell) was chosen for the final chlorophyll value.

Front. Front strength was derived by Chris Orphanides using the five day sea surface temperature composites previously described. Since fronts were based on five day composites, a front must have persisted for several days to be included in this dataset (Chris Orphanides, pers. comm., September 2007).

Frontal strength is the maximum differences in temperature between a cell and its neighboring cells, which includes an area of approximately 12 kilometers. This calculation was created with a custom Python script in ArcGIS (Chris Orphanides, pers.

comm., September 2007). Front data associated with a point location was given a priority; however, when this was not available, a median area was used.

Bottom temperature. Bottom temperature was utilized in addition to sea surface temperature since bottom trawl fishing occurs at the bottom of the ocean, and the conditions can vary greatly between the surface and the bottom. As previously discussed, bottom temperature may impact the groundfish species present on a given day; thus, it may determine the presence or absence of dolphins as well.

Bottom temperature was estimated from a climatology map developed from research cruises of the Marine Resources Monitoring, Assessment and Prediction (MARMAP) program from 1977 through 1987. Measurements were taken on three to six cruises per year at over 180 sampling locations (Mountain 1989). Temperatures were measured using water bottles and reversing thermometers. In 1987, some of the measurements were obtained with a conductivity/temperature/depth (CTD) instrument. Each measurement has an accuracy of approximately -0.02°C. Temperatures were considered bottom temperatures when they were obtained within 10m of the bottom.

The TEMPEST computer program uses the bottom temperatures obtained from MARMAP to estimate bottom temperatures for any day of the year on the northeast continental shelf (Mountain 1989). Using latitude, longitude, and day of year from the observer program data, the program estimated corresponding bottom temperatures by weighting the temperatures of the nearby MARMAP stations based on distances from the stations to the desired location.

Model

After accounting for species, animal condition, and study area, 99.9% of observed hauls from 1996 through 2005 resulted in zeros, or no bycatch. Thus, data analysis of the observer data began as a zero-inflated case by using a conditional model with a quasi-binomial model to model the incidents of ones and zeros or hauls with takes and no takes. For the bycatch events, both a quasi-Poisson and a quasi-binomial model were considered; however, only three events occurred where more than one dolphin was taken in a haul. To avoid biases produced by having only three events drive the model, it was determined that a conditional model was not appropriate for this analysis. Instead, a quasi-binomial model was chosen to analyze the observer program data. This methodology is similar to the logistic regression, with a link function of log (p/1-p) where p is the probability of an event (Dobson 1990). However, the quasi model was chosen to allow the overdispersion factor to vary from 1. The following model was used to fit the presence or absence of bycatch to environmental and fishing-related covariates:

$$p_i = \frac{\exp(\beta o + \beta_1 * x_{1i} + \beta_2 * x_{2i} + \ldots)}{(1+\exp(\beta o + \beta_1 * x_{1i} + \beta_2 * x_{2i} + \ldots))}$$

where p is the probability of event i (in this case bycatch), βs are the parameter estimates, and x represents the covariates, of which there can be any number.

This methodology used only the first part of the conditional model due to the extreme rarity of bycatch events that involved more than one animal. The binomial model estimates the probability of an event either occurring or not occurring; thus, it will not need to account for zeros in excess of what is expected from this distribution. However, since there are so many zeros in this dataset, the model may underestimate the probability of an event by attempting to fit the zeros in the data (Ernst Linder, pers. comm., October 2007). It is also possible that the parameter estimators will be biased due to incomplete and variable detectability (MacKenzie et al. 2004). In other words, an absence in the dataset was treated as a true absence even though a bycatch event may have occurred in an area but was undetected by the observer program; the bycatch event may have occurred on a haul not covered by the observer program or when an observer was not present (i.e. asleep) during a haul.

The model was run in S-PLUS 7.0. Covariates tested in the quasi-binomial model included the environmental variables previously described: depth, bottom slope, sea surface temperate, front, and chlorophyll. Additional variables included haul duration, statistical reporting area, and tow speed for each haul, obtained through the observer program data, and northing and easting, which were derived from the latitude and longitude coordinates for each haul.

After careful consideration, it was decided that bottom temperature would not be included in this analysis. Bottom temperature can vary a few degrees from year to year (Jim Manning, pers. comm., September 26, 2007); therefore, using only one year of data or data from 1977 through 1987 will fail to accurately represent bottom temperature for 1996 through 2005. Furthermore, Murawski and Finn (1988) indicated that species' distributions are affected by interannual variability in bottom temperature; therefore, it was decided that it would be inappropriate to assume that bottom temperature from 1977 through 1987 represented bottom temperatures for the study period.

Similarly, year was also considered for inclusion in the analysis but in the end was not included. This decision was made because it was expected that bycatch rate would be equal across all years in the study and that the spatial pattern of bycatch would be consistent across all years. Quarter, or season, was also excluded from the analysis. Due to the rarity of observed bycatch events, particularly in the summer and fall, it was determined that it was not possible to provide accurate models to fit the data during these seasons without biases due to inadequate data.

Interaction terms between the main effect terms that were deemed biologically meaningful were also tested in the model, including SST and statistical area and depth and bottom slope. The covariates were tested with a manual stepwise procedure, or by testing each main effect and interaction term one at a time. Model selection was based on an F-test to test the significance of each main effect and interaction term at an alpha level of 0.05. Formal model diagnostic methods were not applied given the results of the model, which will be discussed later in this paper.

After the model was selected, model residuals were created to investigate whether a spatial pattern existed in the data. The S-Plus module 'spatial' was used to fit variograms to the model residuals. The variograms showed no spatial pattern, indicating random error existed without any spatial correlations present. Furthermore, there is no existing method for analyzing or interpreting residuals from binary data; thus, this information is not useful for model diagnostics or for modeling residuals (Ernst Linder, pers. comm, September 24, 2007). As a result of the variogram analysis and the difficulty of interpreting binary residuals, no further spatial analysis was considered. However, due to the rarity of bycatch in the Northeast bottom trawl fishery, it was expected that adding a term to account for spatial patterning would not significantly improve the fit of the model or the probability of detecting bycatch.

GIS

The next step in this study was to create a map of the probability of bycatch. Once a model was fitted to the observer data, it was mapped in geographic information software (GIS). Using ArcMap 9.2, several layers of environmental data were created for the study area, including:

Sea surface temperature. Sea surface temperature was obtained for March and April of 2005 from the AVHRR Pathfinder 5 satellite from NASA's Jet Propulsion Laboratory (http://poet.jpl.nasa.gov/). Rationale for using March and April data will be discussed in the Results section of this paper. The spatial resolution of the obtained data was 4 kilometers, and the minimum quality was set to the best quality available. The average sea surface temperatures were calculated using the raster calculator in ArcMap 9.2, and a new grid layer was created. The new grid layer had missing values where either of the original grids had missing data. To account for this, in ArcToolbox using the data management tool 'mosaic to new raster,' another grid was created that filled in the missing values by taking the values from the original April and March 2005 datasets. The sea surface temperatures ranged from 1.01 to 11.85 degrees Celsius, with a mean of 4.62 degrees Celsius.

Bottom depth. Bottom depth was obtained from the 'etopo2' dataset of the National Geophysical Data Center. It is in a 2-minute cell resolution. Bottom depths that were at least 10 fathoms, or 18.29 meters, were used in this study. The deepest depth was 438.91 meters, and the mean depth was 138.88 meters.

Bottom slope. Bottom slope was derived by Chris Orphanides at the National Marine Fisheries Service using the etopo2 depth dataset. He created the raster by projecting the dataset into a Lambert Conic Conformal projection with meters as the units and then by running the ArcGIS slope function. Bottom slope ranged from 0 to 8.17, and the mean slope was 0.29.

All of the rasters were projected into the Geographic Coordinate System North American 1927. The final model was run in ArcMap 9.2 by building the model in the raster calculator and using the rasters described above. Since the rasters used in the model were of various cell sizes, they were resampled with the smallest cell size of 0.33 from the depth layer to minimize error from interpolation.

The model was then displayed with contour lines for depth, created using the Spatial Analyst surface contour function. The contours were based on the 'etopo2' dataset but translated into fathoms, which is the unit of depth most often used by fishermen.

Results

Model

The observer data from 1996 through 2005 indicated that 65 hauls involved Atlantic white-sided dolphins that were either alive or classified as freshly dead; three of the hauls had more than one dolphin: two hauls with two individuals and one with seven. A preliminary model was first tested using data from all years and all months. This preliminary model produced what appeared to be spurious correlations (i.e. a grossly over-parameterized model). Since the dataset incorporates effort at all times of the year, this model exacerbated the problems of rare event modeling. To minimize the biases associated with rare event data, data from March and April were selected. These two months represent the time of greatest concern based on bycatch observations at this time which amounted to 42 hauls with Atlantic white-sided dolphin bycatch.

Significant variables in the model using data from March and April of 1996 through 2005 include the main effects, depth (D) ($p<0.001$) and sea surface temperature (SST) ($p<0.001$), and an interaction between depth and bottom slope (BS) ($p<0.05$). The quasi-binomial model for the probability of bycatch using the observer program data is represented by the following model:

$$p(\text{bycatch}) = \frac{\exp(\beta o + \beta_1{*}SST + \beta_2{*}D + \beta_3{*}BS + \beta_4{*}D{*}BS)}{(1+\exp(\beta o + \beta_1{*}SST + \beta_2{*}D + \beta_3{*}BS + \beta_4{*}D{*}BS))}$$

The parameter estimates or β values, in addition to p-values, are shown below (Table 1).

Variable	**Parameter estimate**	**Standard errors**	**p-value**
Intercept	-6.41	0.90	
Depth	-0.02	0.003	<0.001
Sea Surface Temperature	-0.42	0.15	<0.001
Bottom Slope	2.09	1.29	0.416
Depth*Bottom Slope	0.012	0.009	0.047

Table 1. Parameter estimates and significance levels for the variables in the model.

GIS

The model, mapped in ArcGIS 9.2, showed the highest probability of bycatch to be located in deep areas of Wilkinson Basin, Jordan Basin, and Georges Basin (Figure 2). According to the model, areas surrounding the basins have the next highest probability of bycatch. The probability of bycatch is low throughout the study region, with the majority of the study area having a probability less than 0.004.

Discussion

The results of the model indicate that bycatch is related to sea surface temperature, depth, and an interaction between depth and bottom slope. Sea surface temperature may play a role in describing where bycatch is likely to occur since it is related to where dolphins are found. Selzer and Payne (1988) found that Atlantic white-sided dolphins inhabited areas between 40° and 44 °N latitude and in temperatures ranging from 1 and 13.2°C. In over 97% of sightings, the animals were in water below 12 ° C. In contrast, common dolphins were found in locations with a significantly higher mean surface temperature than white-sided dolphins (Selzer and Payne 1988). Similar to Selzer and Payne's (1988) findings, Summers (2002) found that temperature was the most important variable in describing the distribution of white-sided dolphins in the Northwest Atlantic. Thus, temperature may be important in describing where bycatch likely occurs since it is a highly important factor in describing where white-sided dolphins are found. It is possible that Atlantic white-sided dolphins behave differently in certain sea surface temperature ranges that lead to their entrapment in fishing gear.

Another possibility for the importance of sea surface temperature in describing bycatch is that prey availability may also impact dolphin distribution and that availability is influenced in part by temperature (Summers 2002). Numerous studies have associated prey species of white-sided dolphins, including short-finned squid (Brodziak and Hendrickson 1999), Atlantic herring (Maravelias 1997), and silver hake (Perry and Smith 1994), to specific temperatures similar to those preferred by Atlantic white-sided dolphins. However, it is more likely that bottom temperatures have a greater influence than sea surface temperature on the distribution of groundfish species targeted by the bottom trawl fishery.

Depth is also significant in the model. Similar to sea surface temperature, depth is important in describing the distribution of white-sided dolphins (Summers 2002). Depth can also be associated with prey availability (Brodziak and Hendrickson 1999). Selzer and Payne (1988) noted that both white-sided and common dolphins were associated with areas of high relief. They further point out that these areas have been known to concentrate prey, which secondarily affect the distribution of cetaceans. In this model, an interaction between bottom slope and depth was significant, possibly because of the importance of high relief areas to prey species due to favorable conditions for primary productivity resulting from upwelling and the concentration of nutrients. Mixing of water masses in these areas is also important for prey species (Maravelias 1997). The map of the bycatch probability model indicates that bycatch is probable on or along the edges of three main basins within the study area, including Wilkinson, Georges, and Jordan Basins, which may suggest that the depth or depth and slope interaction play a role in making bycatch in these areas highly probable (Figure 2). It is important to note though that the majority of Georges Basin falls outside the boundaries of the United States' waters, meaning the bottom trawl fishery does not operate in this area.

On the other hand, the high probability of bycatch on or near these three basins suggests that depth is highly influential in driving the model. Raw data from the observer program indicates bycatch is also occurring South of and in between the Georges and Wilkinson Basins. However, according to the model, this area has a lower probability of bycatch than the deep depth areas of the Basins. This lower probability may result since the high fishing effort and relatively rare occurrence of bycatch in the area south of the Basins result in a low probability of bycatch. On the other hand, the model may be inaccurately describing the probability of bycatch due to the rarity of bycatch events. The latter suggests that models based on rare bycatch events from observer program data will inaccurately describe where bycatch events are likely to occur, which will have significant impacts on bycatch mitigation efforts.

Probability of Bycatch of Atlantic White-sided Dolphin
by the Northeast Bottom Trawl Fishery
Based on Fishery Observer Records

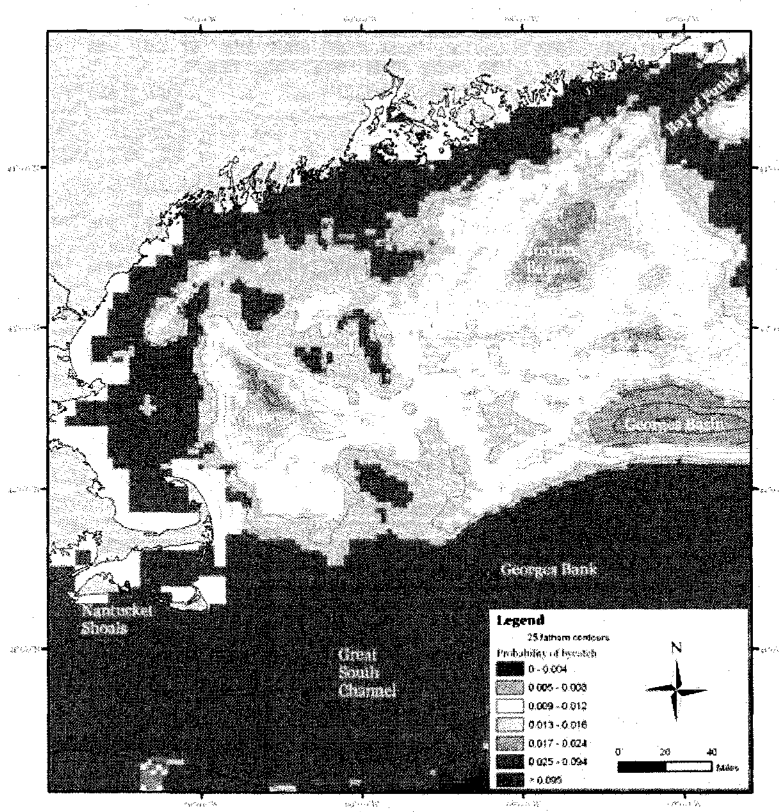

Figure 2. The probability of bycatch of Atlantic white-sided dolphins is highest in deep regions, including Wilkinson Basin, Jordan Basin, and Georges Basin in the Northwest Atlantic; however, the probability of bycatch is low throughout the region.

Similarly, sparse data, resulting from rare bycatch incidences or low observer coverage, make it difficult to understand patterns of bycatch on a temporal scale. In this study, only the months of March and April were included in the model due to sparse data. It is unknown if bycatch actually occurred more frequently during this time of year, or if more frequent occurrences of bycatch were detected by increased observer coverage during these months. Observer program coverage is estimated on an annual instead of a monthly or seasonal basis. Due to the variable nature of animal distribution and fishing effort between seasons, it is not appropriate to assume that spatial patterns of bycatch will be consistent throughout the year. For these reasons, formal model diagnostics were not applied to the model which requires additional information to improve its explanatory power.

If conservation efforts or fishery regulations are based on poor predictions of the spatial and/or temporal occurrences of bycatch, not only will they fail to reduce bycatch, but they could also have profound and unnecessary impacts on the fishing industry. The risk of negatively impacting cetacean communities also exists if managers fail to recognize the changes in seasonal distribution or impacts of displaced fishing effort.

To minimize adverse impacts of relying on sparse and rare bycatch data that may lead to inaccurate predictions and ineffective mitigation strategies, another source of information can be combined with observer program data to test its validity. Fishermen have a wealth of knowledge from their time at sea. By incorporating knowledge of fishermen into descriptions of spatial and temporal patterns of habitat use and bycatch, scientists and managers can not only more accurately describe these patterns, but they can also more effectively create strategies that will reduce injury and death to animals, be supported by fishermen, and minimize impacts to industry.

CHAPTER III

USING TRADITIONAL ECOLOGICAL KNOWLEDGE OF FISHERMEN TO REDUCE ATLANTIC WHITE-SIDED DOLPHIN BYCATCH IN THE NORTHWEST ATLANTIC BOTTOM TRAWL FISHERY

Introduction

Bycatch of marine mammals occurs globally, yet observations of the events are often rare. As a result, scientific data on marine mammal bycatch are limited, and the sparsity of the data presents problems in developing models to depict the spatial and temporal patterns of these events and in devising appropriate mitigation strategies (see Chapter 2). This study aims to determine if an additional source of knowledge, that of fishermen who spend their time at sea and interact with marine life, can complement scientific knowledge about marine mammal bycatch and can inform management efforts. The study will also investigate whether fishermen's knowledge can provide valuable information about the ecology of marine species. As a case study, this paper focuses on marine mammal bycatch, specifically of Atlantic white-sided dolphins (*Lagenorhynchus acutus*), in the bottom trawl fishery for groundfish in New England in the United States. Surveys of fishermen are conducted to determine the utility of their knowledge for understanding marine species' habitat use, mitigating dolphin bycatch, and contributing to management efforts.

Science versus TEK

Traditional ecological knowledge (TEK) from fishermen has been frequently ignored in fisheries management and the conservation process (Macnab 1998, Bird et al. 2003). Although new research is integrating TEK into conservation efforts within small, artisanal fisheries (Bird et al. 2003, Aswani and Lauer 2006, Grant and Berkes 2007, Hall and Close 2007), acceptance and use of TEK has been much slower in industrialized fisheries. Fishermen have repeatedly expressed that their knowledge is neglected and treated as anecdotal due to its qualitative nature (Hall-Arber and Pederson 1999). Yet, this valuable information can complement science research (Macnab 1998, Moller et al. 2004), and can play an integral role in environmental management and marine protected area planning (Macnab 1998).

For the purposes of this paper, TEK will refer to traditional ecological knowledge from fishermen. TEK consists of detailed observations from fishermen based on often decades of experience on where and when they fish and what they catch (Bergmann et al. 2003). This knowledge differs from science knowledge in a number of ways. Due to fishermen's years of experience, their knowledge provides long-term information, usually about a local area (Neis et al. 1999, St. Martin 2001, Moller et al. 2004, Close and Hall 2006, Hall and Close 2007). TEK is often referred to as being place-based since it consists of detailed local knowledge of distribution and harvest patterns on a relatively small spatial scale (Moller et al. 2004, Close and Hall 2006). This knowledge enables fishermen to notice changes in the environment over time (Hall and Pederson 1999, Moller et al. 2004, Grant and Berkes 2007, Hall and Close 2007). Qualitative observations of the environment are stored over many years (St. Martin 2001), and are often passed down through generations (Bergmann et al. 2003, Grant and Berkes 2007). Since TEK is already possessed by communities, this information is generally inexpensive and exceeds science knowledge in sampling density (Bergmann et al. 2003, Moller et al. 2004).

In contrast to TEK, science knowledge usually offers broad, short-term observations over a larger spatial scale (Moller et al. 2004). This information is quantitative in nature. The collection of science knowledge is expensive and thus, limited in sample size. Science knowledge often is unable to detect changes over time due to the limited duration in sampling. Moller et al. (2004) provided an example of these limitations of science knowledge. Aerial surveys of a caribou herd in northern Canada detected dangerously low population declines, which resulted in the development of a management body consisting of government managers and local hunters to address this problem. Communication with local hunters provided information about the caribou herd that the scientists were unable to discern. The caribou herd had split into two groups, and one group was now outside the survey area, preventing scientists from detecting the true cause of what appeared to be a population decline (Moller et al. 2004). In this example, aerial surveys provided a quantitative glimpse of the caribou herd in time but were unable to explain the patterns they detected. This example demonstrates how science can benefit by combining TEK and science information and by building partnerships that address conservation challenges (Wilson 1999, Moller et al. 2004).

Science knowledge and TEK both offer pieces of a larger puzzle, thus combining these two types of observations can provide a better understanding of ecological patterns as a whole. Together, these types of data can increase sample sizes, combine quantitative and qualitative data, compare short-term and long-term patterns, and piece together local area and broader scale knowledge (Moller et al. 2004). Moller et al. (2004) also provided an example of how a partnership between science and local knowledge can enable a better understanding of ecological patterns. In northern Quebec, aerial surveys used for monitoring populations indicated the number of beaver lodges throughout a large territory but failed to identify if a lodge was actually used by beaver. On the other hand, local hunters were able to provide information on which lodges in an area were occupied, but they did not know the total number of lodges in the territory (Moller et al. 2004). This study is designed to test how science and local knowledge can complement one another and can be used to inform monitoring and management efforts, particularly of marine mammal bycatch.

Other benefits of TEK

There are other benefits of including TEK in environmental and conservation management. Tyler (1999) explained that public policies and government regulations often aggravate natural resource problems that they aim to ameliorate. While this may be the case, it is also possible that regulations actually do improve natural resource problems but are not perceived that way by regulated stakeholders. These conflicts usually stem from local stakeholders feeling their interests are ignored or secondary to conservation objectives (Tyler 1999). This neglect of local interests may be the result of inadequate data (Tyler 1999), or of stakeholder interests being excluded from the process (Hall-Arber and Pederson 1999). By incorporating TEK into the environmental management process, a better understanding of ecological patterns can be achieved, and additionally, information sharing can increase transparency, resolve conflict, and build trust if used appropriately (Tyler 1999). It can also lead to science or policy that is more likely to be believed and accepted by multiple stakeholder groups (Neis et al. 1999). TEK can assist in developing resource management strategies in a participatory way by involving local stakeholders (Aswani and Lauer 2006), which benefits the community, increases utilization of valuable information, garners support of the regulated community, and improves the effectiveness of management (Kruger and Casey 2000).

By incorporating TEK into the management process, managers can develop a sense of stewardship or responsibility among local stakeholders (Bird et al. 2003). This incorporation allows stakeholders such as fishermen to see themselves as playing an integral role in creating conservation plans (Bird et al. 2003). Fishermen can contribute by sharing their observations and knowledge instead of acting solely as boat drivers (Bird et al. 2003). Utilization of TEK will lead to conservation measures that are more likely to be effective and supported by stakeholder groups (St. Martin et al. 2007).

Additionally, stakeholder groups, such as fishermen, know how to respond to signals in their environment, often acting proactively before a significant change is noticeable (Moller et al. 2004). This information can help to identify adaptive management measures. Local stakeholder knowledge can be useful in monitoring conservation efforts to ensure they are achieving the desired results. Daily observations by fishermen can be used to monitor management measures in a cost-effective and participatory manner, allowing for adjustments to be made quickly and efficiently (Bird et al. 2003).

Information from TEK can provide observations on a number of processes in the environment. For instance, many studies have demonstrated that TEK could provide valuable information about habitat usage of marine species at different life history stages, particularly as they relate to characteristics of their environment including bottom type

(Neis et al. 1999, Hall-Arber and Pederson 1999, St. Martin 2001, Bergmann et al. 2003, Aswani and Lauer 2006, Anonymous 2006). TEK is also believed to be useful for locating harvest areas (Aswani and Lauer 2006, Close and Hall 2006, Hall and Close 2007), sighting rare or endangered species (Aswani and Lauer 2006), detecting species' seasonal variation (Anonymous 2006), and understanding multi-species interactions (St. Martin 2001, Anonymous 2006). Neis et al. (1999) found that fishermen had local knowledge of fish behavior and movements that could help identify seasonal and directional movements in fish populations and could be used in stock assessments. TEK can also offer insight into how stakeholder groups will respond to or be impacted by management measures (Aswani and Lauer 2006, Hall and Close 2007, St. Martin and Hall-Arber 2006). Much of this information provided by TEK can contribute to informing ecosystem based management or marine protected area planning (Anonymous 2006, St. Martin et al. 2007).

The Northwest Atlantic Marine Alliance (NAMA) organized a series of workshops to elicit TEK from fishermen in order to understand ecosystem scale relationships in the Gulf of Maine (Anonymous 2006). Theoretically, the resulting knowledge could be used to aid in the development of ecosystem based management. Murray et al. (submitted, as cited in St. Martin et al. 2007) introduced a study which based interview questions of fishermen on questions pertaining to ecosystem based fisheries management. The information from the interviews was presented at meetings to elicit discussion on a range of policy and management recommendations and on the future of resource-dependent fishing communities (Murray et al. submitted, as cited in St. Martin et al. 2007). Thus, as more and more studies define how to design and implement ecosystem based management, TEK and local participation will likely play an integral role.

Another area where TEK has and will continue to play an important role in informing fisheries management is in planning for marine protected areas or other time and area fishery closures. It is a widely accepted idea that marine protected areas can be beneficial in protecting ecosystems and buffering overfishing (Macnab 1998). Where protected areas are placed is a more contentious issue (Macnab 1998). Not only can TEK can be useful in determining appropriate placement of closures or protected areas, but local support is necessary for marine protected areas to be successful (St. Martin et al. 2007). Therefore, it is important for stakeholders and their local knowledge to be included in the design of these areas (Hilborn et al. 2004). In a study that compared the effectiveness of two marine reserves in the Philippines, researchers found the reserve that involved stakeholders in the design and implementation phases more successfully achieved its intended ecological benefits (Russ and Alcala 1999, as cited in Scholz et al. 2004).

An example from California also demonstrated the importance of involving stakeholders, the utility of TEK, and the need for socioeconomic considerations in developing successful marine protected areas (Scholz et al. 2004). A panel assembled in 1999 of multiple stakeholder groups to review the Channel Islands National Marine Sanctuary failed to reach a consensus on allocation of marine reserves. As a result, a design that incorporated only some of the consensus areas agreed upon by the panel was selected for implementation. In the selection of this alternative design, many fishermen felt that their TEK and the socioeconomic impacts of closing areas to fishing were not sufficiently considered (Scholz et al. 2004). Similarly, when the California Department of Fish and Game (CDFG) began planning for additional protected areas under the Marine Life Protection Act (MLPA), they failed to solicit stakeholder input and presented draft maps that resulted in an uproar and intense distrust from many stakeholder groups, particularly fishermen. As a result of these outcomes, the CDFG decided to start the process over and to use TEK in planning for the MLPA to create a more successful network of protected areas. The CDFG commissioned scientists to create methodology for integrating TEK into the planning process (Scholz et al. 2004).

Similar to marine protected area planning, identification of time and area fishery closures could benefit from, but often fails to consider, local perspectives. According to St. Martin (2001), a proposed fishery closure in the Gulf of Maine did not sufficiently acknowledge differential impacts on two categories of fishermen. The New England Fishery Management Council devised a spatial management plan, consisting of rolling two-month-long closures, to address overfishing of Atlantic cod (*Gadus morhua*). Based on research using mapping exercises and oral history interviews, St. Martin (2001) concluded that the proposed plan failed to consider fishing patterns and the likely effects on inshore fishermen. According to St. Martin (2001), inshore fishers argued that they were to be excluded from fishing in areas closest to them and that they no longer had access to areas further away due to the implementation of permanent closures. Despite the critique of the management plans expressed to the researchers by some fishermen, the rolling closures were actually proposed by other fishermen, and the effects on inshore fishermen were part of the discussion (Andy Rosenberg, pers. comm., July 2008). While this example addresses issues of socioeconomic impacts rather than TEK per se, it highlights the importance of evaluating whether what has come to be considered common knowledge by some is in fact truly known and/or representative of the diversity of local interests. Since fisheries management efforts impact fishermen differently (e.g. offshore versus inshore fishermen) and since not every fishermen knows or understands the impacts of management on each group of fishermen, one way to ensure the accuracy of social impact assessments, for example, is to interview a sample of fishermen that is representative of the entire fishery (Madeleine Hall-Arber, pers. comm., September 2008). Similarly, interviews with a representative sample of fishermen achieved through careful selection to ensure that the interests and knowledge of the entire fishery are considered is more likely to lead to TEK.

St. Martin (2001) noted that the interviewed fishermen were not opposed to spatial management; in fact, many fishermen expressed that they preferred closures of areas over numeric management methods such as quotas or total allowable catch. Fishermen expressed a preference for small, short closures like the proposed rolling closures compared to large, permanent ones (St. Martin 2001). Inshore fishermen opposed the rolling closure plan, according to St. Martin (2001), due to a perceived inequity since they were the ones most impacted by the proposed closures. In a study by St. Martin and Hall-Arber (2006), fishermen often expressed a feeling of injustice when area-based management affected fishing communities unequally. By involving these stakeholders in the discussion, information regarding how fishermen will respond to management measures such as marine protected areas can be discerned, and inequalities in management can be avoided (St. Martin and Hall-Arber 2006). Thus, using TEK and encouraging stakeholder involvement is and will continue to be an essential component of marine protected area planning.

Fishermen also have the ability to play integral roles in identifying bycatch mitigation strategies. Gilman et al. (2005) noted that the knowledge and experience of fishermen can be tapped into to develop practical and effective solutions to mitigate bycatch. They also identified fishermen as some of the most qualified people to develop innovative strategies to address the problem of bycatch (Gilman et al. 2005), in part due to their ecological knowledge about how marine animals relate to their environment. Rogers et al. (1997) indicated that fishermen have commonly made changes to gear and to fishing practices in an effort to reduce bycatch (Rogers et al. 1997).

In addition, TEK from fishermen has utility in identifying time and area fishery closures that would minimize bycatch, such as of protected species. Hall and Close (2007) demonstrated that TEK could be used to identify harvest "hotspots" and areas of high use by fishermen. TEK also has the potential to identify similar patterns for bycatch "hotspots." By combining information about important harvest areas and high bycatch locations, fishermen, managers, and scientists can work together to determine if closures are appropriate bycatch mitigation measures. Ideally, time and area closures can be identified that minimize bycatch in hotspot areas while still allowing fishermen to fish in areas with a lower likelihood of conflict. For instance, McDaniel et al. (2000) suggested closing fishing areas with low shrimp trawl effort but high sea turtle abundance would not only prevent sea turtle bycatch, but it would also minimize economic loss for fishermen.

Due to the utility of TEK in protected area and closure planning and possibly for ecosystem based management, the usage of TEK is slowly becoming more common in and acceptable for fisheries management. TEK has been identified as being important for management under the Magnuson-Stevens Fishery Conservation and Management Act. The Act insists that fishery management councils use information from local knowledge to complement science data (Hall-Arber and Pederson 1999). However, whether managers chose to only use TEK or to also include resource users in the management process may be important in determining the success of management or conservation efforts. Additionally, for TEK to become part of the regular operating procedures in industrialized fisheries management, several changes to current operations are still needed, including acceptance of qualitative and participatory data collection methods, improved cooperation and trust between stakeholder groups, and willingness to apply TEK to the management process (St. Martin et al. 2007).

Methods for ascertaining TEK

There are several ways that TEK can be ascertained and then used in the management process. Some of the methodologies used to collect TEK for application to public policy and natural resource management include surveys, interviews, and focus groups. Information through surveys in the past have been collected through the mail or over the telephone (Rea and Parker 1997); however, with the increasing accessibility and use of the internet, online survey software has become a common route for collecting data for academic use (D'Agruma and Zollett 2006). Surveys can be beneficial for researchers as they are cost effective and convenient (Rea and Parker 1997). Furthermore, they allow for anonymity for the respondent who may feel more comfortable answering questions if he cannot be seen by the interviewer (Rea and Parker 1997). On the other hand, it will be difficult for an interviewer to establish credibility and to develop trust with the respondent (Rea and Parker 1997). Although the telephone and internet offer large scale access to a number of respondents, they also introduce bias since not everyone has access to these technologies for communication. A further disadvantage of telephones is that they cannot make use of visual aids such as graphs, charts, pictures, or maps (Rea and Parker 1997). Mail surveys often have low response rates and can be time consuming for an interviewer to acquire data (Rea and Parker 1997).

Since many public policy or natural resource management questions involve controversial issues or suggest the potential for new regulations, investigation of these requires the development of trust between a researcher or interviewer and the respondent. Consequently, interviews are a more appropriate method for collecting TEK in many circumstances than surveys. For instance, Bergmann et al. (2003) found interviews produced better results than mailed surveys since they allowed a trust to develop between scientist and fishermen and answers were elaborated on through conversations. Like surveys, interviews can be conducted over the telephone with open ended questions, allowing for more discussion, but they face some of the same disadvantages as telephone surveys. Interviews can also be performed face-to-face with a respondent. Face-to-face interviews allow interviewers to ask respondents to provide details to questions, explain unclear answers, and use visual aids (Rea and Parker 1997). Interviewers can also clarify questions for respondents. In-person interviews provide flexibility to researchers for reaching people who are difficult to communicate with via telephone, mail, or internet (Rea and Parker 1997). These interviews usually have high response rates, but they can be costly, stressful, and sometimes more dangerous for an interviewer (Rea and Parker

1997). Additionally, an interviewer may introduce bias by how he asks questions, or responses to questions may be biased due to reduced anonymity or perceived approval or disapproval of the interviewer (Rea and Parker 1997).

Scholz et al. (2004) used in-person interviews to gather information for the California marine protected area planning process and achieved a ninety percent response rate. They used a snowball sampling method to identify potential respondents. Snowball sampling is a sampling method in which a researcher identifies respondents and asks them to identify others who may qualify for a study (Rea and Parker 1997). This approach is useful for identifying a sample of local "experts" (Neis et al. 1999). Scholz et al. (2004) identified thirty fishermen who were recommended based on their knowledge, fishing experiences, and willingness to participate in their study. The interviews were semi-structured, allowing for conversations to follow questions and for the use of nautical charts for respondents to identify important locations (Scholz et al. 2004). Follow-up interviews allowed the researchers to verify the aggregated results of the study with participating fishermen. Scholz et al. (2004) found that fishermen were concerned about confidentiality of their identification and of the information they provided.

Similar approaches have been used in other natural resource studies. Aswani and Lauer (2006) also used open-ended, structured interviews with experienced fishermen who were identified through the snowball sampling approach. Several studies cite the importance of using maps in face-to-face interviews for collecting data such as fishing or harvest locations or habitat areas (Hall-Arber and Pederson 1999, Close and Hall 2006, St. Martin and Hall-Arber 2006). Similar to Scholz et al. (2004), Close and Hall (2006) noted confidentiality issues in using TEK that pertain to a fishermen's livelihood, such as harvest locations. St. Martin and Hall-Arber (2006) found that fishermen were willing to provide information about where their community fishes since they were not divulging secrets about their own fishing practices.

One approach that St. Martin and Hall-Arber (2006) as well as other public policy studies have used to gather sensitive TEK is through participatory studies. Participatory studies involve volunteers or paid community members who take part in a study by assisting in data collection, such as by conducting interviews. These studies are also beneficial since participants are more likely to care about and support the results of the study and to include issues that are important to stakeholders (Krueger and King 1998). A form of participatory research that has been quite successful in New England is known as collaborative or cooperative research. Cooperative research can span a broad range of topics or approaches. Early efforts were often limited versions of cooperation in which scientists chartered a boat from fishermen to use as platforms for their research. As cooperative research has developed, however, more efforts are being made to develop an equal partnership between fishermen and scientist. One multi-stakeholder-driven cooperative research program in New England, the Northeast Consortium, was designed to facilitate an exchange of information and collaborative research projects in addition to developing mutual respect and trust between stakeholders (Hartley and Robertson 2006a,b). The Northeast Consortium was developed to address multiple issues including the increasing need for industry input into science and management, the distrust between stakeholder groups, and socioeconomic hardship among fishermen and others in coastal communities (Hartley and Robertson 2006a). Hartley and Robertson (2006b) found that cooperative research did in fact facilitate learning among both scientists and fishermen, with each expressing a greater understanding for fishing methods and fishermen's knowledge (TEK) and science, respectively, and a greater respect and trust for one another. However, the limited involvement of managers in the cooperative research resulted in skepticism about the impact of these joint efforts on management (Hartley and Robertson 2006b).

Studies that aim to bridge a gap between communities, such as between managers and stakeholders, may also benefit from using an outside interviewer. Then, a respondent will share information he is comfortable sharing with individuals outside of his community. Studies can also train members of a community such as a fisherman to interview other members within their community. Krueger and King (1998) suggest that a community member may get better results than a researcher if a respondent is more comfortable talking to or sharing information with someone from his community. Regardless of which approach is selected, it is important the respondent knows the intended use of his or her knowledge. Either approach to collecting TEK can be applied to face-to-face interviews with a single respondent or to focus groups.

Focus groups are simply interviews with a group of respondents who discuss topics raised by the interviewer (Morgan 1998, Bechhofer and Paterson 2000). By definition, groups are constituted of individuals with some sense of a shared identify (Clark 2002); thus, members of a focus group are selected on the basis of sharing some attributes. Focus groups are appropriate for learning about groups of people, thus they work best when they involve a group of people who are comfortable discussing issues in front of one another (Morgan 1998). Focus groups have been used to identify and test public policies prior to implementation (Krueger and Casey 2000). They allow organizations to identify policies that are easy to understand, follow, and enforce, and those that are likely to be supported by the communities they impact (Krueger and Casey 2000). Focus groups have been used to test survey or interview questions for interpretability or to collect data. For instance, Hall and Close (2007) tested four map designs with a small group of local harvesters to determine the most appropriate choice for use in the main data collection method of in-person interviews. The previously discussed study conducted by the NAMA used focus groups consisting of fishermen and scientists that were designed to provide information on biological and ecological characteristics of species in the Gulf of Maine (Anonymous 2006). One benefit of focus group studies is that they provide a built-in peer review process since fishermen have been found to perform quality checks to make sure the information provided was complete (Macnab 1998).

Compared with other data collection options, focus groups can be costly for the researcher and the participants. They can also require a greater time commitment for both parties involved. Compared with in-person interviews in which the researcher generally goes to the respondent, focus groups require participants to set aside time to participate in the group discussion. Participation in a focus group may require fishermen to take time off of fishing. One way to encourage participants' involvement is to pay them for their lost income, which results in additional costs for the researcher. Researchers are responsible for planning, recruiting, implementation, and analysis costs associated with focus groups (Rea and Parker 1997). Implementation costs can be quite high once location, accommodation, food, and technical requirements are taken into account (Rea and Parker 1997).

Another methodology that has been used in public policy, natural resource, and coastal zone management applications is that of geographic information systems (GIS) (see Bartlett and Smith 2005). Today, focus group and in-person interviews that use maps or charts are making use of GIS to synthesize and visualize the gathered data. The information provided by stakeholders can be digitized into GIS and allows for visualization of important resource use and habitat areas (Hall and Pederson 1999, Aswani and Lauer 2006, Close and Hall 2006, Hall and Close 2007, St. Martin and Hall-Arber 2006). Thus, GIS can be an important way to empower stakeholders by providing the means to visually present their knowledge (Macnab 1998, Aswani and Lauer 2006).

Macnab (1998) noted that more authority is often given to TEK when it is placed in GIS and combined with other data sources. GIS provides a medium for merging TEK with science knowledge (Close and Hall 2006, Hall and Close 2007, St. Martin and Hall-Arber 2006). The resulting maps can not only be used to identify areas of concern for local stakeholders, but they can also be used to inform management (Macnab 1998). For instance, Aswani and Lauer (2006) developed techniques to depict local socio-spatial knowledge to inform marine protected area planning. The same techniques could be applied to other forms of fishery closures, such as to reduce bycatch. Maps generated in GIS can be used to generate conversations with stakeholders such as on the impacts of regulations on resource use patterns and practices by stakeholders (St Martin and Hall-Arber 2006).

Although initially costly, GIS can be a cost effective research strategy by acting as a database for combining existing data sources (Aswani and Lauer 2006). Merging existing data sources, such as science knowledge and TEK, is more cost and time effective when compared to collecting additional data. GIS, however, often requires an expertise and initial costs that would be prohibitive for local communities without the assistance of an outside researcher. This limitation though does encourage collaborative efforts, which are often beneficial to both parties.

Criticisms of TEK

Collaborative research that utilizes TEK, as discussed throughout this paper, can be beneficial for scientists, managers, and stakeholders such as by including stakeholders in conservation efforts and informing management; however, there are also several criticisms of utilizing TEK. First of all, concerns over the validity and accuracy of TEK are one of the main barriers to the utilization of this local information (Aswani and Lauer 2006, St. Martin et al. 2007). It is always possible that stakeholders will not tell the truth or provide all of their knowledge, limiting validity of the knowledge they provide. Despite criticism of TEK validity, some studies show that stakeholder knowledge is often valid. For instance, St. Martin and Hall-Arber (2006) indicated that fishermen found charts created from vessel trip report (VTR) data to be surprisingly accurate, even though many claim that VTR and logbook data which are self-reported by fishermen are inaccurate. TEK accuracy can be validated by comparing it with science knowledge (Aswani and Lauer 2006). GIS offers a tool for comparing data from TEK with traditional science datasets to verify its accuracy. In cases where there is agreement between TEK and traditional science, the results of a study possess less uncertainty and are more convincing to resource users (Neis et al. 1999). On the other hand when disagreement exists between TEK and scientific research, TEK may offer new hypotheses to be tested.

A similar criticism of TEK is that stakeholders may be unwilling to provide information during interviews or focus groups due to issues relating to confidentiality. As previously discussed, fishermen have expressed reluctance in sharing secrets of harvest locations with competitors (Macnab 1998, Hall-Arber and Pederson 1999, Scholz et al. 2004). Similarly, fear exists within fishermen that their knowledge will be misused to craft regulations that cause harm to them (Hall-Arber and Pederson 1999, Bergmann et al. 2003, Scholz et al. 2004). These concerns are often based on past experiences that have created distrust towards managers (Scholz et al. 2004). From a manager's perspective, these confidentiality issues raise concerns over how the TEK once acquired can actually be utilized.

Concerns over confidentiality are valid and must be considered when devising a study to utilize TEK. St. Martin and Hall-Arber (2006) approached the reluctancy of fishermen in sharing their trade secrets by asking fishermen to describe overall fishing patterns of members of their community instead of their individual fishing practices. Prior to approaching fishermen, they also created charts of existing knowledge based on VTR data which demonstrated that the researchers intended to share information as opposed to solely extracting TEK for their own benefit (St. Martin and Hall-Arber 2006). By establishing a reciprocal relationship with stakeholders, scientists and managers can work to rebuild trust with fishermen and can involve community members in conservation and management (St. Martin 2001). These steps towards participatory management can reduce questions about confidentiality. However, it may take years to repair broken trust between stakeholder groups, and in some cases, the relationship may be irreparable.

In addition to questions about validity and confidentiality, another question raised about TEK pertains to its utility towards informing management. TEK may not be collected in a standardized or consistent manner (Murray et al. submitted, as cited by St. Martin et al. 2007). Thus, there are concerns about how to use TEK in informing management that requires standardized sampling procedures, such as stock assessment reports. One argument in response to these concerns is that collaborative research could be initiated to train fishermen to participate in research and collect data that is appropriate for these uses. On the other hand, TEK may not be appropriate for use in all analyses. Even if TEK is deemed too incomplete or inconsistent for use in stock assessments, this paper has provided many other examples of the utility of TEK such as for understanding ecological patterns; identifying harvest locations, habitat areas, and fishing activity or bycatch hotspots; and informing protected area placement.

TEK can be merged with science knowledge to create a better understanding of spatial and temporal patterns of marine species and fishing activities than a single source of data can provide. This combination of knowledge can lead to conservation and management efforts that are more likely to be successful, due in part to the support of local communities. Past experience has taught us that no single stakeholder group can be as effective in resource management as stakeholder groups working together (Wilson 1999). This lesson should guide our efforts in creating reciprocal relationships between stakeholder groups as we strive to achieve successful conservation of marine resources.

Methods

The aim of this study was to interview commercial bottom trawl fishermen targeting groundfish in New England to ascertain the utility of their TEK for understanding the ecology and bycatch of Atlantic white-sided dolphins and for developing fisheries management strategies. Interview questions were created and then discussed separately with three New England bottom trawl fishermen who collectively constituted an advisory group. Wording of questions, category options for several questions, and scale and features of a geospatial map were discussed with each fisherman to ensure proper understanding of fishery operations by the interviewer and of the interview questions by the respondents. The comments and suggestions of each fisherman were incorporated into the final interview questions and maps.

Captains of bottom trawl fishing vessels in Maine, New Hampshire, and Massachusetts that target groundfish were selected to participate in the interviews. Initial interview respondents were identified with the assistance of academic and independent research groups and nonprofit organizations. A snowball sampling approach was then implemented in which interviewed fishermen identified other bottom trawl fishermen within the study area who qualified to participate in this study. Confidentiality of all interviewees was guaranteed.

Each interview was conducted in person, using a face-to-face interview methodology. The interviews were semi-structured with guiding questions to allow for conversations to occur and for fishermen to identify other ecological or bycatch patterns they detect or to discuss other relevant management issues of importance to them.

As previously mentioned, a geospatial map was used to facilitate communication regarding where observer program data from the NMFS indicates a higher probability of Atlantic white-sided dolphin bycatch exists and whether this map is consistent with the fishing experiences of New England bottom trawl fishermen (Figure 3). It was explained

Map Used for Fishery Interviews Depicting the Probability of Bycatch of Atlantic White-sided Dolphins

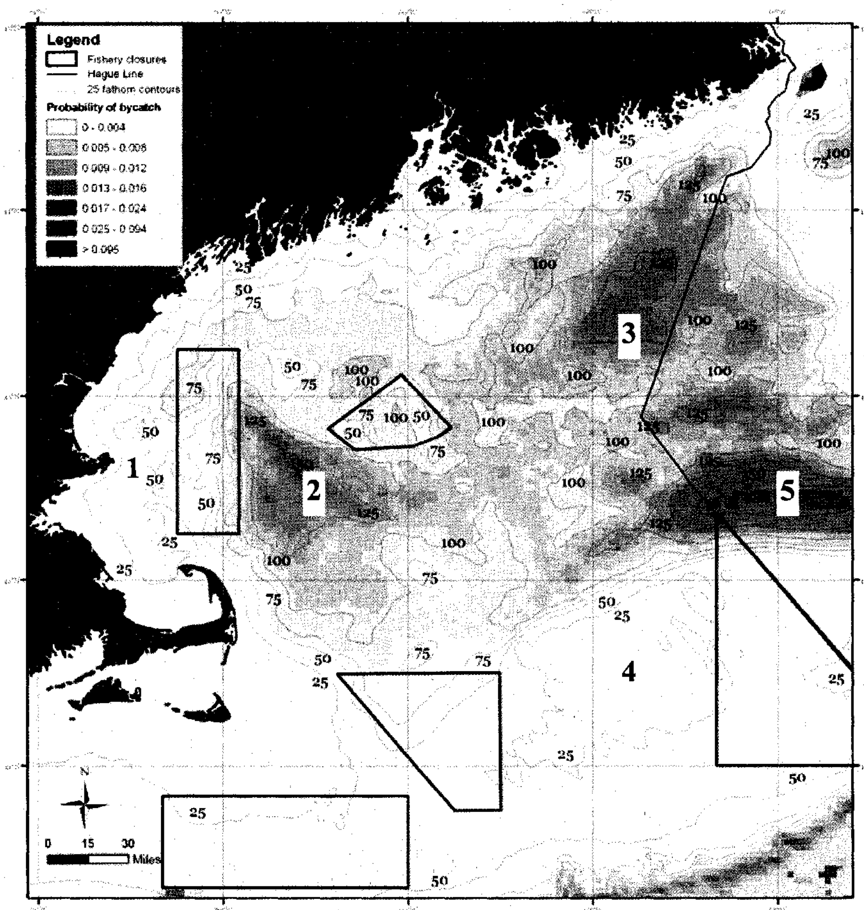

Figure 3. The geospatial map indicates the probability of bycatch of Atlantic white-sided dolphins in the New England bottom trawl fishery for groundfish during the months of March and April. This map was created using a quasi-binomial model of observer program data collected by the NMFS from 1996 through 2005 and includes sea surface temperature, depth, and an interaction between slope and depth. The numbers on the map correspond with fishing areas or ocean features including (1) the western Gulf of Maine, (2) Wilkinson Basin, (3) Jordan Basin, (4) Georges Bank, and (5) Georges Basin.

to fishermen that the map displays bycatch data from the months of March and April; however, fishermen were asked to identify and explain occurrences of bycatch throughout the year. According to this map, a higher probability of dolphin bycatch exists in offshore fishing areas when compared to inshore fishing areas; thus, an effort was made to include large fishing vessels that tend to fish in offshore areas, including Wilkinson Basin and Georges Bank. These fishermen were more difficult to speak with since they are often on fishing trips that can be up to nine days in length, and they usually are only at home for one to two days between trips. Many of the captains of these large, offshore fishing vessels were interviewed when they are on their 'block,' which is a mandatory 20-day period of no fishing that is required of each fishing vessel within a two-month timeframe in the spring of each year. This block is designed to reduce fishing effort on spawning cod stocks. These fishermen are also more likely to be fishing during the months of March and April, the months included in the map depicting the probability of bycatch, due to rolling fishing closures in inshore fishing areas.

Results

Interviewee characteristics

Thirty-one interviews of bottom trawl fishing captains were conducted in Maine, New Hampshire, and Massachusetts. Fourteen of these interviewees had homeports in the area around Gloucester, Massachusetts, ten along the Maine coast, six along the New Hampshire coast, and one in Boston. The vessels operated by the interviewed fishermen consisted of thirteen boats that were less than fifty foot in length, ten that measured between fifty and seventy feet, and eight that spanned more than seventy feet in length (Figure 4).

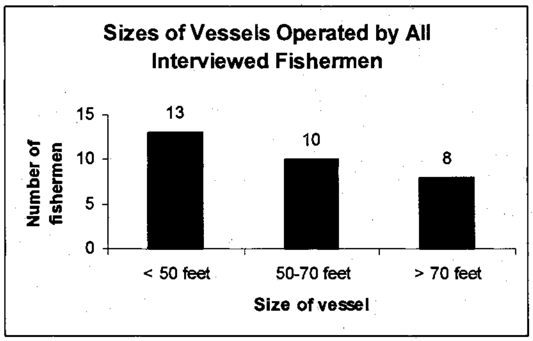

Figure 4. Each interviewed fisherman provided the size of the vessel he operates while targeting grounding in the New England bottom trawl fishery.

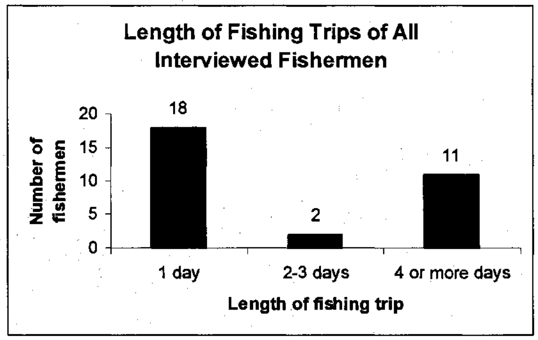

Figure 5. Each interviewed New England bottom trawl fisherman provided the length of an average fishing trip for groundfish.

The size of the vessel was usually correlated with the length of the fishing trips, with the larger vessels usually going to sea for greater lengths of time. Eighteen fishermen responded that they conducted day trips, two answered that they fished for an average of two to three days, and eleven had trips greater than three days in length (Figure 5). In most cases, the longer the trip, the further the fishermen went offshore to fish. The areas identified by fishermen as their primary or secondary fishing areas included offshore greater than fifty miles and Wilkinson Basin each of which was chosen by seven interviewees, the eastern Gulf of Maine which was selected by thirteen respondents, West of the Western Gulf of Maine closure which was the response of nineteen fishermen, and mid-coast Maine which was the response of two fishermen (Figure 6).

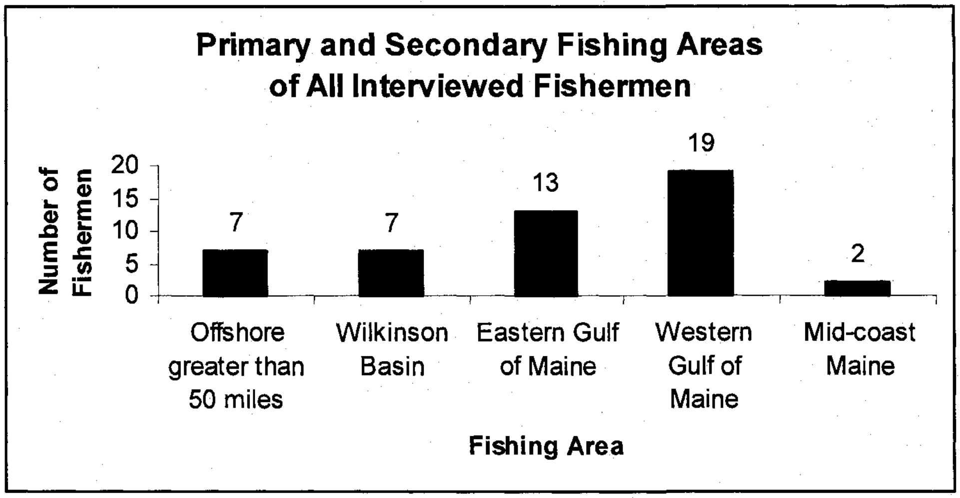

Figure 6. Each interviewed New England bottom trawl fisherman identified his primary and secondary fishing areas for groundfish.

The interviewed fishermen targeted multiple species when fishing in this groundfish fishery. Cod was the primary species targeted by twenty fishermen. Additional species that were identified by interviewed fishermen as targeted species consist of multiple flounder species (17) including grey sole or witch flounder (*Glyptocephalus cynoglossus*) (6), Northern shrimp (*Pandalus borealis*) in the winter (14), Atlantic monkfish (*Lophius americanus*) (13), haddock (*Melanogrammus aeglefinus*) (10), and Atlantic pollock (*Pollachius pollachius*) in the winter (9); the numbers in parentheses were the number of respondents who indicated they targeted the species. Other fish that were targeted by fewer fishermen included American plaice (*Hippoglossoides platessoides*), American lobster (*Homarus americanus*) caught incidentally, whiting or silver hake (*Merluccius bilinearis*) in the summer, and Atlantic herring (*Clupea harengus*).

Ecological factors

Interviewed fishermen were surveyed to determine if fishermen could provide valuable information on ecological factors relating to dolphin presence. When asked if they saw more than one kind of dolphin or if they knew the differences between the different marine mammal species, fifteen of the interviewed fishermen said they did not know the difference between dolphin and porpoise species while fifteen said they could tell a harbor porpoise (*Phocoena phocoena*) from a dolphin, but they did not know the differences between dolphin species such as Atlantic white-sided dolphins and common dolphins (*Delphinus delphis*). This response was expected and instead of asking questions about a particular species, interview questions were framed to ask about dolphin observations and about bycatch in general. Only one fisherman who is very involved in fisheries management answered that he saw and knew the difference between observed dolphin species.

Regarding the frequency of dolphin observations by fishermen, twelve of the thirty-one interviewed fishermen said they saw them daily, seven observed them several times per week, six categorized their observations as occasional, three said they saw them very rarely, and three fishermen could not categorize their observations of dolphins. Eight interviewees offered that marine mammals, including dolphins and harbor porpoise, were around more in the last year or last several years than ever before. Several related their increased abundance to a decreasing presence of mid-water trawlers in the area. Concerns with mid-water trawl gear will be discussed later in this paper (see page 94).

When speaking of the frequency of dolphin observations, most fishermen qualified their answer by saying it depends on the season. However, when asked which season they are most likely to see dolphins, most fishermen responded that they saw dolphins in more than one season. Summer was the most frequently identified season by sixteen fishermen (Figure 7). Nine fishermen identified the fall, three responded winter, and four chose spring as a season in which they observed dolphins (Figure 7). One fisherman said he saw dolphins around the change of the seasons, and two fishermen responded sightings occurred year round. Several fishermen noted when they see dolphins also may depend on when they are fishing. For instance, one fisherman who said he saw more dolphins in the winter noted that most of his fishing effort is in the winter because of rolling closures, a form of fisheries management.

Most fishermen (23 out of 31) responded that dolphins can be seen anywhere; however, a few other responses included near-shore Massachusetts waters, Georges Bank, Jeffrey's Ledge, Wilkinson Basin, Cashes Ledge, the eastern Gulf of Maine, and near Mt. Desert and Sagat Rocks. Another fisherman specifically said he does not see dolphins on Jeffrey's Ledge. Three fishermen specifically mentioned Middle Bank, also known as Stellwagen Bank, as being a hotspot for whales in the spring and early summer when sand eels were present; however, there were differing responses as to whether or not this area is also used by dolphin species.

Fishermen were asked whether where they see dolphins could be related to bottom type, depth, or contours. Sixteen fishermen responded that they could not detect patterns related to these factors, six said dolphins were around deep water, one said shallow water, six said soft bottom, and two said dolphins are associated with edges. Those fishermen who responded soft bottom, meaning mud or sand, as where they see dolphins also noted that they may see dolphins in these areas because it is where they fish.

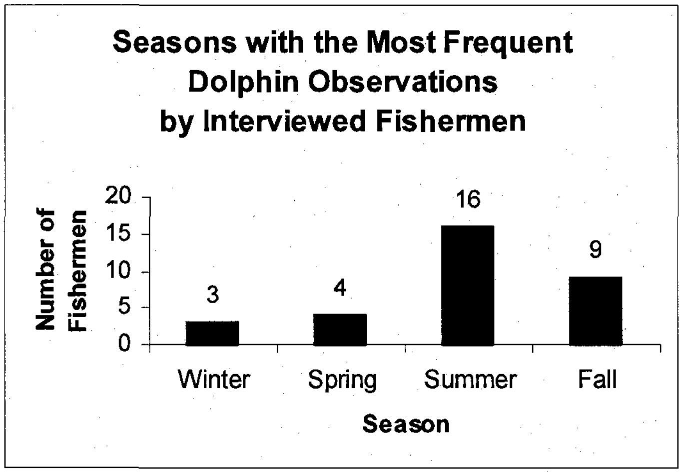

Figure 7. Interviewed New England bottom trawl fishermen identified the seasons in which they most frequently observed dolphins.

The majority of fishermen (18 out of 31) reported that dolphins can be seen at any time during the day. Weather also did not seem to make a difference on when dolphins were sighted as fishermen either said that dolphins were seen in all kinds of weather or that they are easier to see during calm weather since rough weather can make it difficult to observe the animals.

Dolphins were observed feeding, traveling or swimming, bow riding, playing around the boat, following the boat or net, and eating fish out of the net. Fishermen were asked whether dolphins were associated with a bait species. Fourteen responded that they are predominately associated with herring, and six responded they are associated with mackerel (*Scomber scombrus*) and herring. Other bait species chosen by one or several fishermen included sand eels or sand lance (*Ammodytes americanus*), shrimp, squid (*Illex* *illecebrosus* and *Loligo pealei*), whiting, and pollock. Several fishermen specifically mentioned that they see more dolphins when there was feed or bait around, which may be indirectly related to depth or water temperature. Another fisherman pointed out that both marine mammals and fishermen follow bait. Five fishermen did not think there was an association between dolphins and bait, and four responded that they do not know.

Fishermen were also asked if dolphins were more likely to be around when they were targeting a particular species. Seventeen of the thirty-one interviewed respondents answered no to this question, but several others indicated dolphins were around when they targeted shrimp, whiting, or cod, most likely because herring were also around. One fisherman noted that human activity determines where dolphins are, explaining that dolphins, or marine mammals in general, use fishing as an opportunity for feeding.

Finally, fishermen were asked whether they see dolphins during particular times related to their fishing activities. Fifteen responded during haul back, seven said while towing, and two answered when setting the gear. The seven that responded towing noted that when they are towing they are free to look around which may play a role in why they see dolphins during this time and not during others. Eleven fishermen did not believe dolphins were associated with particular times during their fishing practice.

Bycatch information

Ten out of thirty-one interviewed fishermen indicated they caught a dolphin that was either alive or freshly dead while fourteen said they only picked up decomposed dolphins that had already been dead. The other seven fishermen indicated they had never caught or picked up a dolphin in their bottom trawl fishing gear.

Of the ten fishermen who responded that they had caught an alive or freshly dead dolphin, only five believe it was alive when it entered the net, four were unsure, and one said he believed it was dead when it entered his net. Most of these fishermen indicated that dolphin bycatch was an extremely rare event. Seven had only caught between one and five dolphins in an average of thirty years of fishing. Two indicated dolphin bycatch occurs a couple of times a year while one individual said he catches an average of six animals each year, including dolphins, whales, and seals. Two fishermen said that dolphin interactions with fishing gear and bycatch had increased in the last few years despite less fishing effort.

The interviewed fishermen with dolphin bycatch came from varying homeports, including the Gloucester, Massachusetts area (6), Portland, Maine (2), the Seacoast region of New Hampshire (1), and Boston (1). Two of these vessels were less than fifty feet, two were between fifty and seventy feet, and six were greater than seventy feet. One fisherman thought that bigger fishing vessels probably catch more dolphins since they have a bigger net, are more powerful, and haul back the gear faster; however, two other fishermen explained that they have a large boat and tow faster than smaller boats, but they still said that bycatch was rare. According to the bycatch probability map discussed with fishermen, bycatch tended to occur offshore, which is fished primarily by larger fishing vessels.

Six of the fishermen with bycatch indicated their primary or secondary fishing area was offshore or greater than fifty miles (Figure 8). This category included the Great South Channel and more importantly, Georges Bank. Five fish either primarily or secondarily in the western Gulf of Maine and four in the eastern Gulf of Maine, which included Jordan Basin (Figure 8). Only two mentioned they fished in Wilkinson Basin as secondary fishing grounds. The length of the trips of vessels with dolphin bycatch ranged from day trips (4 vessels) to greater than three days (6 vessels).

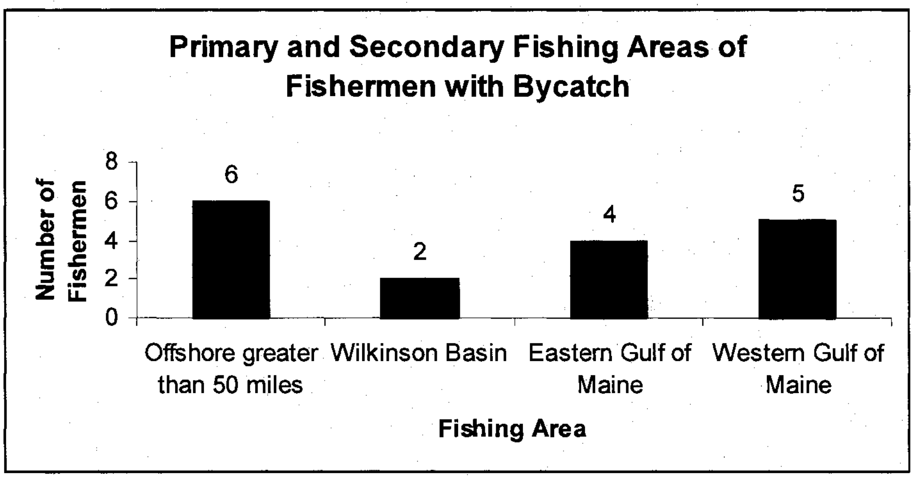

Figure 8. The primary and secondary fishing areas for interviewed New England bottom trawl fishermen who experience dolphin bycatch include offshore fishing areas, Wilkinson Basin, and the eastern and western Gulf of Maine.

Of the three fishermen who had somewhat regular bycatch, all three were captains of boats greater than seventy feet in length. One of these vessels conducted day trips within twenty-five miles of the shore while the other two fished greater than fifty miles offshore. One fisherman said he currently experiences bycatch on Wilkinson Basin while another said he did in the past but no longer fishes there because of too few days at sea. Furthermore, two of these fishermen said they believed that the dolphins may be feeding when they are caught.

When asked whether interviewed fishermen experience dolphin bycatch in the areas on the map that showed a high probability of bycatch, the responses varied greatly, and no specific spatial patterns could be identified. One fisherman said he does not experience bycatch in the deep water on Wilkinson Basin while four said they had experienced bycatch on Wilkinson Basin currently or in the past when fishing in that area. Another fisherman said he expected it more in shoal water. Middle Bank, the north edge of Georges Bank, and areas near Boone Island in Maine were each identified by one fisherman as an area where bycatch has occurred. Two fishermen said bycatch can be anywhere. Fishermen were asked to draw on the maps where their bycatch incidents have occurred. It was explained to fishermen that the probability map displayed data from March and April; however, they were asked to identify any bycatch events or patterns they experienced throughout the year. Only seven fishermen could remember the general location of the events. When comparing the areas drawn by these seven fishermen, none of the areas overlapped, indicating bycatch can and has happened throughout the bottom trawl fishing area. For this reason, the areas drawn by fishermen were not digitized into GIS since the areas were dispersed throughout the New England fishing grounds, producing no discernable spatial patterns to dolphin bycatch. Several fishermen indicated that the map indicated that bycatch is happening in deeper water with a sand and mud-mixed bottom. However, of particular importance, several fishermen mentioned that the areas on the map with the highest probability of bycatch mirrored where trawling effort is now occurring, particularly in Wilkinson Basin, due to changes in fishing practices that have resulted from fishing regulations and gas prices which will be discussed in more detail later in this paper.

When fishermen were asked to identify whether dolphin bycatch was related to sea surface temperature, depth, or slope, no fisherman was able to detect patterns related to these factors. Most indicated it was because bycatch of marine mammals is so rare. Similarly, none of the fishermen said that dolphin bycatch was related to specific times of years or times of day. Furthermore, all of the interviewed fishermen said that there were no areas that they avoid because they are concerned that dolphin bycatch will occur. Several indicated that when one was caught, it was not likely that another would be caught even though marine mammals were often swimming around the fishing gear or on the boat's bow. Fishermen also responded that they never change fishing practices if a marine mammal is in the area. No one indicated that bycatch created a problem for them or that the bycaught animals were hard to get out of their fishing gear. Through informal conversation, fishermen also noted that they did not know that a certain level of marine mammal bycatch was legal through the allocation of a potential biological removal (PBR) for each species.

Four interviewed fishermen volunteered that they believe dolphins are associated with fishing opportunities as they often swim up to the boat and stay for hours or eat fish escaping or sticking out of the net. One fisherman described the dolphins as being dispersed among different boats, and he thought he saw fewer dolphins when more boats were present as a result. Some fisherman believed that dolphins were smart enough not to go into the fishing net and stayed behind the net to feed while three others thought the dolphins probably swam in and out of the net to feed. One fisherman believed that hard turns during towing collapsed the gear and trapped dolphins that were feeding in the net. Some thought the depths at which they fished prevented dolphins from accessing the nets to feed except during haul back.

Three fishermen believe that dolphins are feeding during haul back, possibly even arriving an hour before hauling. When asked whether dolphin bycatch was related to particular times during their fishing, six indicated they believe bycatch occurred during haul back, one said sharp turns may cause bycatch to occur, and three believed setting may play a role. Three other fishermen responded that dolphins avoid you while hauling and setting. There were several different beliefs as to why hauling in gear may lead to bycatch. The responses included that they gear was traversing through the water column where the animals are during haul back, giving them access to the fishing gear and its catch. One fisherman thought the gear was moving faster during haul back while others thought the gear moved slower. The fisherman who catches an average of six marine mammals each year described the gear as becoming more vertical during this time and thought the animals became caught when the gear changed configurations. He noted the animals were usually caught in the mouth of the net. Another fisherman agreed that dolphins were caught in twine at the front part of the net while another observed bycaught animals in the codend of the net. Hauling back gear faster was one suggestion made by a fisherman to reduce dolphin bycatch.

Fishermen were also asked about whether there were ways to reduce catch of dolphins. As previously mentioned, several said bycatch was too rare while a few others had suggestions including a faster haul back may reduce bycatch. Three fishermen said pingers such as those used on gillnets may let dolphins know they are coming. One fisherman suggested a pinger that would be activated a half hour before hauling to scare dolphins away from the gear. Due to concerns with seal interactions, one fisherman noted that the pingers must be at a frequency that would not be heard by fish or seals. In addition to pingers, another fisherman suggested a large grate such as those used as turtle excluder devices to help them get out of the gear, although he also expressed concern that the grate may help them enter the net and feed. Before pingers or grates are tested, one fisherman suggested, it would be useful to put cameras on the fishing gear to understand the marine mammal behavior and to explain why capture occurs.

Although not part of the interview, twenty-three of the thirty-one fishermen that were interviewed voluntarily mentioned that they believe that dolphin bycatch is a problem in another fishing gear type. Eleven indicated that mid-water trawls caught dolphins while seventeen mentioned gillnets as causing dolphin bycatch. Several fishermen noted both types of gear. Three fishermen indicated they had caught a marine mammal using gillnet fishing gear. Fishermen also brought up concerns over mid-water trawls since they target whiting and herring, prey for dolphins; use smaller mesh; tow faster in the middle of the water column; use larger nets; and have extremely low observer coverage. Furthermore, several fishermen indicated that mid-water trawls are allowed to fish everywhere, including in areas closed to the groundfish fleet. One interviewed fisherman was previously a mid-water trawler. He noted the size of midwater trawls can be problematic. For instance, his net took up the entire water column when fishing in 25 fathom deep waters. As a result, this fisherman noted that he regularly bycaught tuna and marine mammals, specifying that weekly he caught four to five tuna in a tow and also that he caught marine mammals on a weekly basis. He believed that the marine mammals were probably feeding on the net and chasing the codend at haul back. He also included that he had heard of up to one hundred porpoise being caught in a single tow with mid-water trawl gear.

Additional topics that were not part of the semi-structured interview were discussed by interviewed fishermen including interactions between other marine species and fishing gear, which resulted in occasional bycatch. Five of the interviewed fishermen voluntarily brought up that they occasionally caught live sharks while two indicated that caught bluefin tuna (*Thunnus thynnus*). Basking sharks (*Cetorhinus maximus*), which are large, filter feeders, were the shark species discussed by fishermen. Fishermen mentioned that basking sharks create big problems for fishermen since they are usually alive when caught, weigh up to eight thousand pounds, and take about an hour to free from the fishing net. One fisherman thought it was unlikely that the sharks survive after disentanglement. This same fisherman thought he caught around three basking sharks per year. Another fisherman believed he caught basking sharks and bluefin tuna when making hard turns with his fishing gear.

Unlike dolphins, one fisherman noted, if you catch basking shark, you are more likely to catch additional animals. For that reason, the fishermen indicated they will leave or avoid a fishing area where basking sharks are found. Two of the interviewed fishermen indicated a pattern to basking shark occurrence and bycatch. They believed that bycatch occurred usually in the late summer when the animals began to move offshore between August and October when water temperatures dropped to around 50-52°F. They noted that the prevalence of basking sharks lasted about one to two weeks and believed their occurrence was linked to a migratory behavior. When comparing bycatch of basking sharks to dolphins, a fisherman called the former an aggravation issue while the latter was a moral one.

Pilot whale (*Globicephala spp.*) and minke whale (*Balaenoptera acutorostrata*) interactions with fishing gear were also discussed by eight and three fishermen, respectively. It is possible additional fishermen had interactions with pilot whales, but they were not included as part of the semi-structured interview. For both species, fishermen noted that they came up to the net to feed on fish either stuck in the net or escaping from it. Pilot whales were associated with fishing effort targeting cod, haddock, hake, and pollock. One fisherman said the pilot whales, which were often sighted in pods of three to four individuals, will swim in and out of the net while two others believed the whales would follow behind the net when it was full. The whales were described by one fisherman as aggressive, and two fishermen had observed pilot whales biting and pulling the codend of the fishing net until it opened.

Fishermen also linked pilot whales to certain periods in their fishing. One thought that pilot whales were linked to changes in the engine noise while another observed the whales mulling around during towing. Six believed pilot whales were related to haul back, which is when at least one fisherman believed the animals were becoming caught in the gear. The interviewed fishermen believed that the occurrence of pilot whales was more likely related to fishing activities rather than environmental conditions such as sea surface temperature, depth, or slope, and it was reported that pilot whales were seen on every fishing trip. Georges Bank was the fishing area primarily discussed in relation to pilot whales. Fishermen noted they either saw lots of pilot whales on Georges Bank or had caught them in this area. One interviewee also noted that turtles in the summer are seen and may be caught on Georges Bank, although he had never caught one. In order to reduce bycatch of pilot whales, one fisherman suggested two strategies including waiting for pilot whales to disperse before bringing the net through the middle of the water column and secondly to set and haul the gear faster when the animals are concentrated around the net to minimize the mid-water interactions.

Sightings and interactions with harbor porpoise were also discussed by interviewed fishermen, although also not part of the semi-structured interview. Five fishermen explained that they saw or interacted with harbor porpoise in the winter when targeting shrimp, possibly because of a co-occurrence of herring with shrimp. Five fishermen believed that the harbor porpoise were feeding on fish, usually herring but occasionally groundfish, while another fisherman thought the porpoise were feeding on shrimp. Observations of harbor porpoise occurred on a daily basis, in nearshore waters. Harbor porpoise were observed to be following the fishing vessels during towing and were also prevalent during haul back, according to five interviewed fishermen. One fisherman explained that when shrimping, haul backs occur every hour or hour and a half compared to ever three to five hours when targeting groundfish. Another fisherman likened setting and hauling of fishing gear to being a dinner bell for harbor porpoise.

Fishermen suggested that although bycatch of harbor porpoise is infrequent, it may be related to when fishing gear is hauled back to the boat. One fisherman noticed that when he caught harbor porpoise in the past, there were many animals present which may have led to the animals becoming confused or disoriented. Other fishermen noted that shrimp fishing effort is declining due to the low price for shrimp and high fuel costs; the decline will reduce interactions with harbor porpoise.

In addition to dolphins, sharks, whales, and harbor porpoise, seals were discussed by interviewed fishermen. One noticed more seals in the last few years, both offshore and in harbors year round. Other fishermen complained about seals becoming a problem by competing for fish, taking bites out of fish, eating fish coming out of a separator grate, or swimming in and out of the net while feeding. One fisherman mentioned he had seen seals with gunshots as a result of interactions with various types of fishing gear.

Fishery management concerns

All interviewed fishermen expressed concern or anger over fisheries management issues. One fisherman said that he was insulted at meetings while another felt as though the information he contributed to fisheries management was treated as anecdotal. Several of the issues discussed by fishermen that were not included in interview questions included cod, discard, and sector management.

One fisherman explained that all management is in place because of cod. There are several management strategies in place including area closures, total allowable catch (TAC) or trip limits, days at sea, and 2:1 fishing areas that are designed to act as disincentives to targeting cod. A 2:1 fishing area is one in which for every day fished, two days are subtracted from a fisherman's allowed days at sea. Interviewed fishermen expressed concern that the management measures lead to increased discards of cod, which are preventing the cod stock from recovering. In addition, one fisherman noted that it makes no sense that the trip limit recently increased from four hundred to eight hundred pounds if we are trying to allow cod to recover.

Other fishermen noted that because of regulations, trips are shorter than in the past. Since it is easiest to target and catch cod, fishermen explained that they get as much as they can catch, particularly in the 2:1 area and return quickly to shore to stop their clock, meaning to stop the deduction of hours from their days at sea. Despite disincentives to target cod, twenty out of thirty-one interviewed fishermen said they target cod. Almost all fishermen who target cod, particularly those that fish West of the Western Gulf of Maine closure, said they catch more than the daily allowance of eight hundred pounds, but since they are not allowed to "run their clock," they end up discarding the extra cod. Many fishermen said the discards are often up to the allowable limit of eight hundred pounds. If they were allowed to "run their clock" and deduct an extra day of fishing when in fact they were tied up at shore, they would reduce the discards of cod and also reduce their fishing effort which would also impact other species that are caught.

Several fishermen noted that other species such as yellowtail flounder and monkfish were not targeted because of their low trip limits. One fisherman suggested fisheries management should implement a total catch limit for the fishery or for fishermen that includes multiple fish stocks in an effort to take an ecosystem approach to fisheries management.

There are two other factors fueling the discards of cod and putting increased fishing pressure on near-shore fishing grounds, namely competition between fishermen and increasing costs of fuel. Competition between resources users was noted by several fishermen. For instance, there is conflict in Maine between lobster fishers and the groundfishing fleet since the former does not want the latter to be able to land lobster that was incidentally captured in trawl gear. As a result many fishermen whose homeport was in Maine are moving to Gloucester, Massachusetts to land incidentally captured lobster. These moves are concentrating fishing effort and increasing pressure on cod stocks. Increased prices of fuel are also impacting fishermen and influencing where they fish.

One fisherman said that he currently spends about $50,000 a month on fuel prices when the fuel costs $4/gallon. This price is expected to continue to rise. This fisherman explained that these fuel prices are causing more fishermen to fish closer to shore, increasing pressure on near-shore fishing grounds.

These factors not only cause fishermen to fish closer to shore, one fisherman explained, but it also causes effort to be focused on a "sure thing" catch like cod. Fishermen reported that it is not worth their time to go out past fishing closures so all of their fishing effort has been reduced to one area. Others noted that Wilkinson Basin, which never used to be a primary fishing area, is now experiencing high fishing effort because of regulations and fuel prices. One fisherman explained Wilkinson Basin is "the only place left to fish."

In addition to management related to cod and discards, many of the interviewed fishermen expressed concern about the upcoming sector management being proposed by the fishery management council. One fisherman described it as "the last ditch effort to save the fishery." There is conflict between how sector allocations should be distributed. One interviewee explains that most bottom trawlers in Maine want their fishing history to lead to higher sector allocations since they have a history of more offshore landings. On the other hand, fishermen in Massachusetts, specifically in Gloucester, have bought permits with days at sea that are not accompanied by history. One fisherman in Gloucester said "You can't just change the rules of the game in the middle of it" when referring to the idea of determining sector allocations based on fishing history instead of days at sea.

Another complaint towards sectors as a management framework included that one fisherman can ruin it for the whole sector. Bycatch and discards of certain species by one member of a sector can prevent the rest of the sector from continuing to fish. As a result, several fishermen indicated they would prefer individual transferable quotas (ITQs) instead of sectors.

Discussion

The goal of this study was to determine if fishermen could provide insight into spatial and temporal patterns of dolphin habitat use and bycatch that offers a more thorough understanding than can be provided from scientific research alone. Thirty-one bottom trawl fishermen in Maine, New Hampshire, and Massachusetts were interviewed to determine the extent of their knowledge about Atlantic white-sided dolphins, the marine mammal species most frequently recorded in the NMFS observer data as bycaught in this fishery. It is believed that twenty to thirty interviewees is a sufficient sample with which to obtain an estimate on the degree of agreement between subjects for a cultural model (D'Andrade 2005), or a model that views a culture, in this case a fishery, based on shared experiences (Quinn 2005). It became clear during the interviews that interviewed fishermen could not identify spatial or temporal patterns related to dolphin habitat use or bycatch; therefore, by interviewing more fishermen, it was unlikely that a better understanding of the interactions could be obtained. Also, since after interviewing thirty-one bottom trawl captains, no new names were produced from fishermen using the snowball sampling approach, it was believed that a representative sample of the fishery was achieved.

Interviews of bottom trawl fishermen indicated that most fishermen did not know the difference between marine mammal species; although about half of the interviewed fishermen responded that they could distinguish between a harbor porpoise and a dolphin. The information provided for the interviews, thus, is not specific to Atlantic white-sided dolphins but to dolphins in general and in some instances may also be relevant to harbor porpoise. Without educational outreach to aid fishermen in identifying different marine mammal species, fishermen's knowledge in regards to marine mammal ecology or habitat use will be limited to broad taxonomic categories.

Through interviews, few patterns related to dolphin presence were identified. Interviewed fishermen could not link their presence to bottom type, depth, bottom slope, weather conditions, or time of day. Although previous research as discussed in Chapter 2 has shown that dolphin presence may be directly or indirectly related to environmental conditions, it is possible that fishermen do not see dolphins often enough to detect these patterns. It is also feasible that fishermen are likely not concerned with, and thus do not take note of, the whereabouts of dolphins as they are with fish species on which their livelihood depends. Fishermen have been known to provide valuable information on spatial and temporal patterns and habitat usage of fish species at different life history stages, particularly as they relate to characteristics of their environment (Hall-Arber and Pederson 1999, St. Martin 2001, Bergmann et al. 2003, Aswani and Lauer 2006, Anonymous 2006).

In this study, the majority of interviewed fishermen did, however, identify the summer (16 out of 31) and the fall (9 out of 31) as being the seasons with the most frequent dolphin observations, suggesting warm water may be important to dolphins.

Previous research has demonstrated that Atlantic white-sided dolphins are more evenly spread throughout the Gulf of Maine in the summer and fall than in other seasons (Selzer and Payne 1988, Northridge et al. 1997), which may explain why dolphin sightings during this time are experienced by a greater number of fishermen who themselves may be dispersed throughout the various fishing areas. Consistent with this finding, the majority of fishermen (23 out of 31) said dolphins could be found anywhere throughout the fishing area. In contrast, interviewees responded that they most frequently observed harbor porpoise in the winter, particularly in near-shore waters while shrimping.

The utility of this knowledge from fishermen is limited since the observations are related to when and where fishing is occurring. For instance, while fishermen's knowledge may help us confirm habitat use of marine mammals, it does not exclude their presence from other areas or times where or when fishing effort is absent. In this study, fishermen's knowledge can confirm that dolphins are likely present in warmer months and harbor porpoise inshore in colder months; however, it is also possible that the animals are present during other seasons or in other areas in the absence of fishermen. For example, Selzer and Payne (1988) found that Atlantic white-sided dolphins prefer colder and less saline waters than common dolphins, and they exhibit seasonal distribution shifts, possibly due to changes in the distribution of prey species. In the winter and spring, the species is commonly found in the southwestern waters of the Gulf of Maine, in the Great South Channel, and on Georges Bank (Selzer and Payne 1988, Northridge et al. 1997). Therefore, although fishermen reportedly observed dolphins most frequently in the summer, the animals are likely present in New England during other times of year, but the lack of observations may result from an absence of fishing effort at the same time and place.

Despite this limitation, fishermen's knowledge can still be useful to scientists. For instance, although Meyer et al. (1979) and Kenney and Winn (1986) found that the occurrence of Atlantic white-sided dolphins coincides with a seasonal peak in abundance of an important prey species, sand lance, interviewed bottom trawl fishermen (20 out of 31) believed that dolphins were associated with the prey species, herring. This observation by fishermen may help scientists better understand the relationship between dolphins and their prey.

Interviewed fishermen also suggested they utilize the same areas as marine mammals because the marine mammals and their target catch, groundfish, may be feeding on the same prey species or that, as appears to be the case with pilot whales, the marine mammals are using fishing operations as an opportunity for feeding. Almost half of the interviewed fishermen (15 out of 31) responded that they saw dolphins during haul back possibly because the animals are taking advantage of the gear and its catch when it passes through the water column. Haul back was also a time when interviewed fishermen thought bycatch may be occurring either because the gear is accessible to the animals, or it is moving slower or changing configurations. Previous research has documented dolphin entanglement in the front of a trawl net in a location where the mesh size was large enough that the dolphin should have been able to swim through safely (Hartmann et al. 1996). Further reports suggested that another animal may have survived entrapment at a similar location, implying that the animal had been caught during hauling since it had not yet drowned (Hartmann et al. 1996). Thus, the knowledge of fishermen and their understanding of gear changes can aid researchers in understanding bycatch and in developing mitigation strategies.

In this study, approximately one-third (10 out of 31) of interviewed fishermen indicated they caught a dolphin that was either alive or freshly dead; however, only three of those fishermen indicated it occurred on a somewhat frequent basis (i.e. at least once or twice per year). Although in studies such as this one, there is often concern over the validity of interview results, this study demonstrates that at least some interviewed fishermen were willing to discuss controversial and sensitive topics such as dolphin bycatch despite the potential ramifications to their fishing operations of added measures to protect these already protected species. Interviewed fishermen may have reported fewer interactions with dolphins than what they truly experienced; however, the results of the interviews are consistent with observer program data that dolphin bycatch is extremely rare in this fishery.

Similar to dolphin observations, fishermen were unable to identify spatial patterns of dolphin bycatch linked to sea surface temperature, depth, or bottom slope, the environmental factors deemed important by the quasi-binomial model (see Chapter 2). In addition, like scientific data which was too sparse to identify temporal patterns to dolphin bycatch, fishermen could not relate dolphin bycatch to specific times of day or year. In this study, dolphin bycatch was too infrequent for fishermen to detect spatial and temporal patterns of the incidents; however, in a fishery with higher rates of bycatch, fishermen's TEK is still expected to complement scientific data in explaining patterns of bycatch. Furthermore, the knowledge obtained from fishermen suggests that interviews can still be useful in understanding other aspects of dolphin bycatch and in shaping effective fisheries management.

For instance, of the fishermen who indicated they experienced bycatch, those with vessels greater than seventy feet constituted a greater proportion of interviewed fishermen than fishermen with vessels in other size classes. In other words, out of the eight interviewed fishermen with vessels greater than seventy feet, six experienced bycatch, which constituted seventy-five percent of those interviewed in this size class. For fishermen operating vessels less than fifty feet, only 15.4% experienced bycatch (2 out of 13), and for those with vessels between fifty and seventy feet, 20% (2 out of 10) indicated they caught an alive or freshly dead dolphin. Similarly, of the fishermen who fished offshore greater than fifty miles, a larger proportion of these fishermen experienced bycatch (85.7%, or 6 out of 7), than fishermen fishing Wilkinson Basin (28.6%, or 2 out of 7), the eastern Gulf of Maine (30.8%, or 4 out of 13), or the western Gulf of Maine (26.3%, or 5 out of 19). Thus, these results confirm that bycatch is more likely to be occurring offshore and with larger vessels, which is what was expected based on the bycatch probability map. The larger vessels are most likely those experiencing occasional bycatch because they are the ones fishing offshore. The higher rates of bycatch seen on Wilkinson Basin were not confirmed by fishermen, possibly because fishermen reported on their fishing experiences over the past twenty years whereas fishing pressure on Wilkinson Basin has intensified only in the past several years as a result of area-based fisheries management and increasing fuel costs, according to interviewed fishermen.

Although TEK in this study could not be used to provide greater detail on the areas or patterns of dolphin bycatch than was already suggested by scientific data, it can be used to confirm the existing information. Additionally, scientists and managers can focus bycatch studies or mitigation strategies on areas with a higher probability of bycatch. Based on these results, it would be recommended to scientists trying to understand dolphin bycatch on bottom trawl vessels to increase observer coverage in offshore fishing areas and to work collaboratively with large, offshore fishing vessels.

Since interviewed fishermen suggested that bycatch mirrors where fishing effort is concentrated, it is important for fishery managers to understand how management strategies will affect fishermen. For instance, a network of fishery closures was designed in 1994 for the New England multi-species sink gillnet fishery. The network was designed to protect harbor porpoise, but it failed to consider the displacement of fishing effort to fishing areas surrounding the closed areas (Murray et al. 2000). Furthermore, some fishermen who were most affected by the closure felt that they unfairly paid the highest price for bycatch reduction. A few fishermen continued to set their gear in the closed fishing area (Murray et al. 2000). As a result of the displacement of fishing effort, continued fishing in the closed fishing area, and variable patterns of bycatch rates, the bycatch rate of harbor porpoises actually increased to levels higher than in 1993 (Murray et al. 2000). This study demonstrates that interviews of fishermen can help managers understand how the fishermen are impacted, and as a result how they respond to, management measures.

Interviewed fishermen confirmed that management for cod has not only concentrated fishing efforts in certain areas, but it has also been ineffective at providing a disincentive for fishermen to target cod. Despite disincentives in places for fishermen to target cod, 64.5% (or 20 out of 31) interviewed fishermen indicated that cod was one of the species they targeted. They described cod as a "sure thing" to catch in their limited days at sea. They mentioned they often caught more than the required fishing limit and since they were not allowed to run their clock and return to port with their catch, they discarded the excess cod. With high levels of discard, it is improbable that cod will recover in the Gulf of Maine, which suggests cod management has not been successful to date, and it has failed to address how fishermen respond to management strategies. Increasing fuel costs to unprecedented levels will further concentrate fishermen into a few fishing areas closer to shore. It will be more important than ever for management to incorporate an understanding of how fishermen will respond to management actions in order to maintain what remains of New England fishing communities and the valuable fish resources. An understanding of how fishermen react to management strategies, including how fishing effort is displaced by area management, will also have impacts on protected species, including marine mammals, sharks, and sea birds, in addition to other marine life. The next chapter of this dissertation will discuss how fishermen's knowledge at sea and how they react to fisheries management can be integrated into the Take Reduction Team process for marine mammal management in the United States.

Although this study focused on a single marine mammal species due to the paucity of NMFS observer records for other bycaught species, it is important for fisheries management to take multi-species and ecosystem effects of fishing into consideration. This study looked specifically at Atlantic white-sided dolphins because they were the most frequently caught marine mammal in observations of bottom trawl fishing operations; however, fishermen also discussed interactions with marine mammals besides dolphins, including pilot whales (8 out of 31), minke whales (3 out of 31), and harbor porpoise (5 out of 31), in addition to basking sharks, none of which were included in the semi-structured interviews. If these species had been formally included in the interviews, it is possible that more fishermen would have shared information regarding these interactions.

For fishermen that target shrimp near-shore in the winter, observations and interactions with harbor porpoise seem to occur regularly. The Northern shrimp fishery is considered a relatively clean fishery of an underutilized species with little to no bycatch. However, currently with high fuel costs and low prices for shrimp, many fishermen are choosing not to target shrimp due to their low profit margin. It is possible though that with changing market conditions, an increase in demand may mean increased interactions with harbor porpoise. This knowledge could allow managers to act proactively and monitor interactions between this fishery and marine mammals, keeping this fishery a good choice for consumers seeking sustainable seafood. It is important for managers to consider the effects of management strategies on multiple species and on the ecosystem. If management strategies are designed for a single species as previously discussed for harbor porpoise in the New England multi-species sink gillnet fishery (Murray et al. 2000), displacement of fishing efforts may not only have detrimental effects on the protected species, but it can also increase bycatch of other species that were not considered by the management actions.

Although the information obtained from fishermen in the bottom trawl fishery in this study was limited due to the rarity of bycatch, the utility of fishermen's knowledge was demonstrated by the identification of interactions with marine mammal and shark species outside the focus of this study and through the discussion of how fishermen respond to management actions. This study proves that communication with fishermen regarding fisheries management is possible. It is also essential to build trust between stakeholder groups. In a fishery with higher rates of bycatch, it is likely that spatial and temporal patterns can be identified by fishermen that provide a more comprehensive understanding of bycatch interactions than can be achieved solely through scientific research. Increasing pressures on the New England bottom trawl fishery in the form of rising fuel costs, extensive fishery management, and in some cases, decreasing fish resources, communication and cooperation is necessary to maintain fishing communities and valuable marine resources.

CHAPTER IV

MANAGEMENT OF MARINE MAMMAL BYCATCH BASED ON DATA FROM SCIENTIFIC RESEARCH AND FISHERMEN'S KNOWLEDGE

Fisheries Management Process

Introduction to Take Reduction Teams

In the United States, commercial fisheries are managed by the National Oceanic and Atmospheric Administration (NOAA). The Marine Mammal Protection Act (MMPA) requires NOAA to protect all marine mammals in United States' waters. In response to high bycatch of marine mammals, section 118 of the MMPA mandates that NOAA convene a team of industry, government, academic, and environmental experts, known as a take reduction team (TRT), to develop a take reduction plan to reduce serious injury and mortality of marine mammals in these fisheries. A team, once convened, has six months to develop a plan to reduce bycatch of marine mammals in commercial fishing gear to levels less than a potential biological removal (PBR) level. PBR is defined as the maximum number of individuals that can be taken from a stock, excluding natural mortality, while still allowing the population to reach its maximum productivity. It is estimated by multiplying the minimum population estimate, one-half of the maximum theoretical or estimated net productivity rate for a stock, and a recovery factor between 0.1 and 1, with 0.5 being the default for non-endangered species.

The long term goal of a take reduction plan, to be reached within five years of the plan's implementation, is for serious injury or mortality of a marine mammal stock to approach zero, also known as the zero rate mortality goal (ZMRG). Plans to reach ZMRG should take into account the existence of bycatch reduction technology, the economics of a fishery, and current management plans for the fishery. ZMRG is attained when incidental mortality of a stock is less than ten percent of PBR. Take reduction plans are designed to remain in existence after bycatch reduction is reached in order to monitor the levels of bycatch.

Traditionally, take reduction teams have been convened in order to protect a particular species, such as bottlenose dolphins, or a group of similar species, such as large whales. The team then must consider in their bycatch reduction plan all fisheries with bycatch of the species. Most recently, NOAA restructured the format of the take reduction teams to be formed around a fishing gear type instead of based on bycaught species. Two of the most recently formed take reduction teams include the Atlantic Pelagic Longline Take Reduction Team and the Atlantic Trawl Gear Take Reduction Team (ATGTRT). These teams consider all impacted species with bycatch above PBR or as deemed significant by NOAA.

The ATGTRT which includes U.S. Northeast and Mid-Atlantic bottom and mid-water trawl fisheries was convened in September 2006 in response to a settlement agreement in April 2003 between the Center for Biological Diversity (CBD) and NOAA that resulted from a lawsuit (TRT 2006). The lawsuit challenged NOAA for failing to implement a TRT to address bycatch of several strategic stocks of marine mammals, or those in which human-caused mortality exceeded PBR (TRT 2007). In 2003, the strategic marine mammal stocks of concern to the CBD included common dolphins (*Delphinus delphis*) and pilot whales (*Globicephala* spp.) (TRT 2007). The settlement agreement required NOAA to convene a TRT to address bycatch of common dolphins and pilot whales in the Mid-Atlantic mid-water trawl fisheries that targets squid, mackerel, and butterfish. NOAA also agreed to conduct surveys and to hire fishery observers for at least two consecutive years to estimate abundance as well as injury and mortality of common dolphins and pilot whales prior to convening the TRT (TRT 2006). NOAA expanded the TRT to include additional trawl fisheries, and they included Atlantic white-sided dolphins (*Lagenorhynchus acutus*) in these studies and in the TRT due to bycatch in these fisheries (TRT 2006).

In 2006, the ATGTRT was convened and tasked with developing a plan to reduce incidental takes of common dolphins, pilot whales, and Atlantic white-sided dolphins. However, by 2006, annual bycatch estimates of all three species were at levels below PBR, meaning the stocks were no longer considered strategic. In addition, after updated abundance data, stock sizes were re-estimated and were found to be higher than previously believed. PBR levels were also re-calculated based on the new population estimates, and incidental injury and mortality remained below PBR (TRT 2007). In April 2007, the ATGTRT convened for a second time, and guidance provided by NOAA's Office of General Counsel determined that the team was not required to adhere to any of the deadlines for producing a take reduction plan since none of the stocks were considered strategic, and they do not interact with category I fisheries, or those in which injury or mortality of a stock in a fishery is greater than or equal to fifty percent of PBR (TRT 2007). Thus, the ATGTRT was in a unique position of voluntarily creating a take reduction plan that focuses on reaching the ZMRG. To date, the ATGTRT has developed a draft document, entitled the Atlantic Trawl Gear Take Reduction Strategy, which identifies education and outreach plans and research recommendations.

Availability of Data

TRTs are designed to use various data sources when devising take reduction plans to reduce marine mammal bycatch. First of all, data is available to the teams regarding stock abundance and structure of marine mammal species under consideration. In addition, the most commonly used data by TRTs are reports by fishery observers of bycatch incidents. Fishery observers on commercial fishing vessels observe fishery operations and collect a variety of information on target and non-target catch, including the location, time, and condition of bycatch incidents and individuals. Unfortunately, due to funding limitations and weather constraints, only a small portion of fishing trips is observed. One trawl fishery in particular, the Northeast mid-water trawl fishery for herring, is believed by interviewed bottom trawl fishermen and some scientists to have a high marine mammal bycatch rate because of the size and speed of the net and due to the presence of marine mammals in the middle of the water column (see Chapter 3). However, the fishery has little to no observer coverage. For fisheries with low observer coverage, few inferences can be made as to spatial and temporal patterns of bycatch which limits the ability of TRTs to identify mitigation strategies. The ATGTRT does not include any Northeast mid-water herring fishermen nor does the current Take Reduction Strategy address this fishery's low observer coverage in its recommendations.

In addition to low observer coverage in some fisheries, rare or sparsely observed bycatch incidents also limit the utility of this information by TRTs. As discussed in

Chapter 2, there are many problems that arise from rare event data in which there are fewer "ones," or occurrences, than "zeros," such as bycatch observations (King and Zeng 2001). Bycatch may be a rare event in many fisheries since its occurrence is extremely infrequent or because cetaceans may be absent from areas covered by fishing gear (Hilborn and Mangel 1997). Thus, there will likely be many hauls with no bycatch and a few hauls with one, two, three, etc… captured animals, as was the case with bycatch in the New England bottom trawl fishery (see Chapter 2). This rarity of bycatch events introduces difficulties in modeling its distribution and allows for inaccurate descriptions of where bycatch is likely to occur. Thus, take reduction plans based on these models alone can lead to ineffectual bycatch mitigation.

Similarly, sparse data, resulting from rare bycatch incidences or low observer coverage, make it difficult to understand patterns of bycatch on a temporal scale. For bycatch in the New England bottom trawl fishery, only the months of March and April were included in the model due to sparse data throughout the rest of the year. Due to the variable nature of animal distribution and fishing effort between seasons, it is not appropriate to assume that spatial patterns of bycatch will be consistent throughout the year.

To minimize adverse impacts of relying on sparse and rare bycatch data that may lead to inaccurate predictions and ultimately ineffective mitigation strategies, TRTs are also designed to be a collaborative process, using information from fishermen's experience at sea. However, fishermen are often reluctant to share information which can be used to develop management strategies that could negatively impact their business. Some bycatch management strategies that have been employed in past take reduction plans include fishing closures or mandated gear modifications, both of which can be costly for fishermen.

Successful TRTs are based on a trust being developed between the parties involved and on a consensus being reached. In a review of past TRTs, Young (2001) found that fishermen were often distrustful of managers; she found that fishermen believed their input was being disregarded by upper level NOAA employees who were not present at the TRT meetings. A survey conducted in 1998 by RESOLVE, the group contracted to facilitate TRT meetings, found that most TRT participants were not satisfied with the results of the take reduction plan (Young 2001). Furthermore, sixty-eight percent of surveyed TRT participants felt that the data the team used was insufficient to support the task (Young 2001). Not surprising, the surveys also found that of all TRT members, the fishing community was least willing to accept the validity of the available data and interpretations derived from it (Young 2001). Many were also skeptical about the methods used to derive abundance and bycatch estimates (Young 2001), possibly because the data at TRT meetings is often presented in a way that is not easily understood by individuals without a scientific background.

Due to the limitations of observer data, the reluctance of fishermen to share their knowledge in a TRT meeting, and a reluctance of fishermen to accept the validity of scientific data, another data source is needed to facilitate communication regarding bycatch interactions at TRT meetings that will result in a successful outcome. In this study (see Chapter 3) and in previous research, it has been demonstrated that interviewing fishermen can provide valuable information, also referred to as traditional ecological knowledge (TEK), about marine species' habitat usage (Hall-Arber and Pederson 1999, St. Martin 2001, Bergmann et al. 2003, Aswani and Lauer 2006, Anonymous 2006), important harvest areas (Aswani and Lauer 2006, Close and Hall 2006, Hall and Close 2007), rare or endangered species sightings (Aswani and Lauer 2006), and multi-species interactions (St. Martin 2001, Anonymous 2006). Additionally, TEK can also offer insight into how fishermen will respond to or be impacted by management measures (see Chapter 3, Aswani and Lauer 2006, Hall and Close 2007, St. Martin and Hall-Arber 2006). Hall and Close (2007) demonstrated that TEK from fishermen could be used to identify harvest "hotspots" and areas of high use by fishermen. TEK also has the potential to identify similar patterns for bycatch "hotspots" in fisheries with a high bycatch rate. This knowledge of fishermen is available, but it has rarely been successfully utilized by TRTs. By incorporating knowledge of fishermen into descriptions of spatial and temporal patterns of bycatch, TRTs will be able to more accurately describe these patterns and to more effectively create strategies that will reduce injury and death to animals, be supported by fishermen, and minimize impacts to industry.

Incorporating Fishermen's Knowledge

Despite the TRT process being designed to incorporate fishermen's knowledge and experience by including fishermen and industry representatives as TRT participants, fishermen are often reluctant to share information within a management framework. Furthermore, few fishermen are involved in the TRT process, and the majority of fishermen are unaware of the process and are unable to provide input. For instance, only one bottom trawl fisherman is a member of the Atlantic Trawl Gear Take Reduction Team. He is unable to represent the perspectives of the entire fishery since there are separate inshore and offshore components. A strategy is needed to integrate information from fishermen into the management process and to involve them in conservation efforts, such as to protect bycaught species. Fisheries management that takes TEK into consideration will more likely lead to effective conservation measures, in part because they provide a better understanding of ecological patterns of marine organisms, consider how fishermen will respond to such actions, and are more likely to be supported by involved stakeholders (St. Martin et al. 2007). Additionally, information that is obtained from fishermen through one-on-one interviews, such as those conducted in this study (see Chapter 3), can differ from that which is being asked of fishermen at the TRT and can be useful in developing bycatch mitigation strategies.

One way fishermen's knowledge can be integrated into the TRT process is to conduct interviews of fishermen in advance of the formation of a TRT just like abundance surveys and fisheries observations were done as part of the settlement agreement before the ATGTRT was convened. TRT members usually react to data and information as it becomes available, whereas information from interviews can provide an information base in advance of a TRT being convened. The information received from interviews may highlight important harvest areas for fishermen, spatial and/or temporal patterns of bycatch that were observed by fishermen but that could not be detected by sparse observer data, impacts of potential fisheries management plans on fishing operations, operational patterns to bycatch including incidents during hauling or sharp turns, or other species that are impacted by the fishery. While this knowledge could be invaluable to TRT participants in forming a take reduction plan, it could also be useful for detecting other spatial and temporal patterns of interest for addressing other conservation issues. It would also provide information that fishermen would feel represents their interests and their experiences, and it would be presented in a way that was accessible to those without a scientific background. Tyler (1999) found that conflicts in public policy and natural resource management usually stem from local stakeholders feeling their interests are ignored or secondary to conservation objectives. Incorporating TEK into the TRT process could help build trust between stakeholder groups, direct the conversations, and assist the teams in creating take reduction plans within the ambitious six month deadline. Thus, it is recommended that future TRTs be preceded by interviews of fishermen in the fisheries that will be involved.

By following this recommendation, TRTs would have at their disposal both TEK and observer data. The different types of data can offer different perspectives on a conservation issue and thus, can be used individually or combined to investigate various options to address the problem. Due to fishermen's years of experience, their knowledge provides long-term information, usually about a local area (St. Martin 2001, Moller et al. 2004, Close and Hall 2006, Hall and Close 2007). It is also place-based knowledge that consists of local knowledge of distribution and harvest patterns on a relatively small spatial scale (Moller et al. 2004, Close and Hall 2006). This knowledge enables fishermen to notice changes in the environment over time (Hall and Pederson 1999, Moller et al. 2004, Grant and Berkes 2007, Hall and Close 2007). Fishermen often know how to respond to signals in their environment, which enables them to act proactively before a significant change is noticeable (Moller et al. 2004). This information can help to identify adaptive management measures. On the other hand, data from observer data or abundance surveys usually offer broad, short-term observations over a larger spatial scale due to the difficulty and expense of collecting this data (Moller et al. 2004). As a result, science knowledge often is unable to detect changes over time due to the limited duration in sampling. It does, however, offer estimates of abundance and bycatch that allow scientists and managers to identify species or fisheries of concern. Adequate observer reports can also lead to models that can predict where, when, or conditions which suggest a high probability of bycatch.

Combining scientific data and TEK provides a better understanding of ecological and bycatch patterns as a whole. By interviewing fishermen and including their knowledge into the TRT process, the teams can better understand patterns of bycatch and can develop more effective strategies to mitigate the interactions. However, in addition to interviews of fishermen, other strategies can be taken and are recommended to include fishermen in conservation and/or management of fisheries resources. These strategies can be applied to marine mammals and the TRT process, utilized for other taxonomic groups, or used for multi-species conservation or even ecosystem-based management objectives. Although the utility of TEK has been criticized when it is not collected in a standardized or consistent manner, this study demonstrates that this knowledge can, in fact, be collected systematically. Thus, the information can and should be incorporated in the stock assessment analyses to validate findings.

One recommended strategy for involving fishermen in sustainable use or conservation of natural resources is through collaborative research. It is recommended that the MMPA fund collaborative research to identify effective means to reduce marine mammal bycatch. Collaborative research is a form of participatory research that has been quite successful in New England but to date has largely focused on identifying sustainable fishing practices for fish species. This technique can include a broad range of topics and levels of collaboration, including one in which fishermen and scientists or gear technologists form an equal partnership to identify sustainable fishing practices or to study ecological patterns of marine organisms. In respect to this study, it can be utilized to collect data on habitat use or bycatch, or to identify mitigation strategies for bycatch of marine mammals and other protected species.

Another strategy for including fishermen in conservation efforts is to develop advisory groups at the local level. Local stakeholder groups can focus efforts on resolving bycatch issues or can operate more broadly at multi-species or ecosystem based levels. It is recommended that independent organizations, such as the Northeast Consortium and the Gulf of Maine Research Institute in New England, guide these efforts and help identify conservation goals for local resource users and other local stakeholders. Local groups can consist of either single or multiple gear types, and meet on a somewhat regular schedule to monitor local conservation issues. While it is recommended that subgroups of fishermen, such as bottom trawlers, be convened to provide valuable information about marine mammal bycatch as part of a TRT, these groups can also provide useful information and promote stewardship among local stakeholders if organized outside of a management regime. It is believed that the most successful strategies to include fishermen in conservation efforts and to instill a sense of ownership among stakeholders will be those that operate at a local level and outside of a management framework. If fishermen, scientists, and environmentalists work together outside of a management framework, a network for collaborative research can be built in addition to necessary trust between stakeholder groups.

Dolphin Bycatch Management

Interviews of bottom trawl fishermen for groundfish in New England provided information that would be useful to members of the ATGTRT. As discussed in Chapter 2, a model was created to map the probability of Atlantic white-sided dolphin bycatch in this fishery based on observer program data, yet the rarity of events resulted in a model that is likely inaccurate and strongly influenced by the environmental factor, depth. As a result, interviews of bottom trawl fishermen were conducted to determine if TEK can provide additional information on the patterns of bycatch in this fishery and on how fishermen would be impacted by fishery management (see Chapter 3). Although the ATGTRT had already convened when the interviews were conducted, they produced useful results that will help the team as they transition from developing a strategy that currently only identifies research and education needs to one that aims to reduce incidental bycatch in trawl fisheries. Even though bycatch of the impacted species is currently below PBR, annual mortality could increase, sending takes above PBR and making the species strategic once again. Information provided by fishermen can also help the ATGTRT develop strategies to reach the ZMRG. Current mortality estimates of pilot whales combine long-finned (*Globicephala melas*) and short-finned (*Globicephala macrorhynchus*) pilot whales into one estimate. NOAA is currently working to understand the spatial separation between these species, which may lead to stocks of one or the other being reclassified as strategic (TRT 2007).

It is important for the ATGTRT to have the tools needed to develop an effective take reduction plan or to identify strategies that maintain incidental takes below PBR and meet the ZMRG. It is also important that the ATGTRT consider all species impacted by trawl gear. Although traditionally take reduction plans addressed bycatch of a single species, bottom trawl fishermen identified other species with which their interactions lead to bycatch. It is important that the ATGTRT use this knowledge to ensure that mitigation measures address multiple impacted species. Efforts to reduce bycatch of a single species also need to take into consideration the unintended effects on other species, such as on basking sharks which interviewed fishermen identified as being caught in trawl gear during a particular time of year.

In the study, both the model and the interviews confirmed that bycatch is very rare in the New England bottom trawl fishery. After mapping the bycatch probability model, several areas, including Wilkinson Basin and parts of the eastern Gulf of Maine, had a slightly higher probability of bycatch than other fishing areas. However, as previously mentioned, the model seemed to be strongly driven by the environmental factor, depth. In addition, due to fisheries management and high fuel prices, fewer and fewer fishermen are fishing in offshore fishing areas, such as Georges Bank. Interviewed fishermen who responded that they experienced dolphin bycatch varied in their responses as to where it occurs. In fact, none of the areas drawn by interviewed fishermen overlapped (see Chapter 3). Since the areas identified by fishermen did not identify consistent spatial patterns to bycatch interactions, this study was unable to develop methodology to spatially combine this information with the results of the bycatch probability model that was developed using observer program data. However, this information obtained from fishermen can still be useful to fishery managers since it suggests that area-based management would be ineffective at reducing bycatch. If bycatch management was based solely on observer data, area-based management would be a consideration of the ATGTRT that would most likely have been ineffective at mitigating dolphin bycatch. Instead, broad scale measures are needed given the dispersion of interactions between dolphins and bottom trawl gear.

A number of fishermen indicated that they believed interactions with marine mammals occurred most often during haul back, instead of during other times during their fishing operations. Possible broad scale measures that could be effective at reducing bycatch in this fishery would be to have fishermen change the speed at haul back or to wait until marine mammals disperse before hauling in their gear. Additional research is necessary to determine if these measures would be effective. Since fishermen identified the summer and confirmed offshore as the time and location for frequent dolphin observations and interactions respectively, this information can be used by the ATGTRT and by gear technologists to test possible gear modifications when and where overlap between dolphins and fishermen is most likely.

Due to the rarity of bycatch events, most fishermen will likely say that interactions with marine mammals are too uncommon to warrant changes in their fishing practices. Therefore, incentives are necessary to give fishermen a reason for changing fishing operations. Collaborative research between scientists and fishermen can determine if techniques exist that reduce interactions while also saving time and money or increasing safety for fishermen. Such benefits would increase the likelihood of mitigation strategies being adopted by fishermen.

Although this study did not identify a bycatch mitigation measure that will definitively reduce dolphin bycatch in bottom trawl gear, it did confirm the importance of integrating fishermen's knowledge into bycatch management in order to effectively mitigate interactions between fishing gear and protected species. This study also identified the need for broad-scale measures over area-based management for addressing dolphin bycatch in bottom trawl gear. Interviews of fishermen also confirmed that bycatch of multiple species occurs, and mitigation measures must be effective at reducing incidental takes of multiple species. Surveys of fishermen or other stakeholder groups can and should be utilized in advance of management implementation in other areas throughout the world to address conservation threats to marine mammals and other marine species. Past experience has taught us that stakeholder groups working collaboratively can be more effective in resource management than single stakeholder groups working in isolation (Wilson 1999). Only when various stakeholder groups are included in and understand the need for efforts to protect natural resources will they be successful. This lesson should guide our efforts to achieve successful conservation of marine resources.

LIST OF REFERENCES

Anonymous. 2006. Ecosystem Relationships in the Gulf of Maine–Combined Expert Knowledge of Fishermen and Scientists. NAMA collaborative report 1: 1-16.

Aswani, S. and M. Lauer. 2006. Incorporating fishermen's local knowledge and behavior into geographical information systems (GIS) for designing marine protected areas in Oceania. Human Organization 65(1): 81-102.

Bakkala, R., W. Hirshberger, and K. King. 1979. The groundfish resources of the eastern Bering Sea and Aleutian Islands regions. Marine Fisheries Review 41(1):1-24.

Bartlett, D. and J. Smith, Eds. 2005. GIS for Coastal Zone Management. Boca Raton, CRC Press. 310 pp.

Bechhofer, F. and L. Paterson. 2000. Principles of Research Design in the Social Sciences. Routledge, London. 172 pp.

Bergmann, M., H. Hinz, R. Blyth, M. J. Kaiser, S. I. Rogers and M. Armstrong. 2003. Using expert knowledge to identify possible groundfish 'essential fish habitats'. *In* Haggan, N., C. Brignall, and L. Wood (editors). Putting Fishers' Knowledge to Work. FCRR 11(1): 189-197.

Berrow, S. D., M. O'Neill, and D. Brogan. 1998. Discarding practices and marine mammal by-catch in the Celtic sea herring fishery. Biology and Environment: Proceedings of the Royal Irish Academy 98B(1): 1-8.

Bird, K. E., W. J. Nichols and C. R. Tambiah. 2003. The value of local knowledge in sea turtle conservation: a case from Baja California, Mexico. *In* Haggan, N., C. Brignall, and L. Wood (editors). Putting Fishers' Knowledge to Work. FCRR 11(1): 178-183.

Broadhurst, M. K. 1998. Bottlenose dolphins, *Tursiops truncatus*, removing by-catch from prawn-trawl codends during fishing in New South Wales, Australia. Marine Fisheries Review 60(3): 9-14.

Brodziak, J. and L. Hendrickson. 1999. An analysis of environmental effects on survey catches of squids *Loligo pealei* and *Illex illecebrosus* in the northwest Atlantic. Fishery Bulletin 97: 9-24.

Canadas, A., R.Sagarminaga, R. De Stephanis, E. Urquiola and P. S. Hammond. 2005. Habitat preference modeling as a conservation tool: proposals for marine protected areas for cetaceans in southern Spanish waters. Aquatic Conservation 15: 495-521.

Chilvers, B. L., and P. J. Corkeron. 2001. Trawling and bottlenose dolphins' social structure. Proceedings of the Royal Society of London B 268:1901-1905.

Chilvers, B. L., P. J. Corkeron, and M. L. Puotinen. 2003. Influence of trawling on the behaviour and spatial distribution of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Moreton Bay, Australia. Canadian Journal of Zoology 81:1947-1955.

Cipriano, F. 2002. Atlantic white-sided dolphin *Lagenorhynchus acutus*. *In* W.F. Perrin, B. Würsig and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. Academic Press, San Diego: 49-51.

Clark, T.W. 2002. The Policy Process: A Practical Guide for Natural Resource Professionals. Yale University Press, New Haven. 215 pp.

Close, C. H. and G. B. Hall. 2006. A GIS-based protocol for the collection and use of local knowledge in fisheries management planning. Journal of Environmental Management 78: 341-352.

Couperus, A. S. 1997. Interactions between Dutch midwater trawl and Atlantic white-sided dolphins (*Lagenorhynchus acutus*) Southwest of Ireland. Journal of Northwest Atlantic Fishery Science 22: 209-218.

Cox, T. M., A. J. Read, A. Solow and N. Tregenza. 2001. Will harbour porpoises (*Phocoena phocoena*) habituate to pingers? Journal of Cetacean Research and Management 3(1): 81-86.

Crespo, E. A., S. N. Pedraza, S. L. Dans, M. K. Alonso, L. M. Reyes, N. A. Garcia, M. Coscarella, and A. C. M. Schiavini. 1997. Direct and indirect effects of the highseas fisheries on the marine mammal populations in the Northern and Central Patagonian Coast. Journal of Northwest Atlantic Fishery Science 22: 189-207.

Culik, B. M., S. Koschinski, N. Tregenza and G. M. Ellis. 2001. Reactions of harbor porpoises *Phocoena phocoena* and herring *Clupea harengus* to acoustic alarms. Marine Ecology Progress Series 211: 255-260.

Cunningham, R. B. and D. B. Lindenmayer. 2005. Modeling count data of rare species: some statistical issues. Ecology 86(5): 1135-1142.

D'Agruma, H.D. and E.A. Zollett. 2006. Web-based survey software for academic research. In Reynolds, Woods, and Baker, eds. Handbook of Research on Electronic Surveys and Measurements. Idea Group Inc., Hershey, PA: 253-263.

D'Andrade, R. 2005. Some methods for studying cultural cognitive structures. *In* Quinn, N., ed. Finding culture in talk: a collection of methods. Palgrave □odeling□, New York: 83-104.

Dans, S. L., E. A. Crespo, N. A. Garcia, L. M. Reyes, S. N. Pedraza, and M. K. Alonso. 1997. Incidental mortality of Patagonian dusky dolphins in mid-water trawling: retrospective effects from the early 1980s. Report of the International Whaling Commission 47: 699-703.

de Haan, D., P. Y. Dremiere, B. Woodward, R. A. Kastelein, M. Amundin, and K. Hansen. 1998. Prevention of the by-catch of cetaceans in pelagic trawls by technical means. CETASEL final report. Contract number AIR III-CT94-2423, 1994-1997. 204 pp.

Diamond, S. L. 2004. Bycatch quotas in the Gulf of Mexico shrimp trawl fishery: can they work? Reviews in Fish Biology and Fisheries 14: 207-237.

Dobson, A. J. 1990. An introduction to generalized linear models. Chapman and Hall, London. 174 pp.

Fennessy, S. T., G. K. Mwatha, and W. T., eds. 2004. Report of the regional workshop on approaches to reducing shrimp trawl bycatch in the western Indian Ocean. FAO Fisheries Report No. 734. Food and Agriculture Organization of the United Nations, Rome, Italy.

Fertl, D., and S. Leatherwood. 1997. Cetacean interactions with trawls: a preliminary review. Journal of Northwest Atlantic Fishery Science 22: 219-248.

Fletcher, D., D. Mackenzie and E. Villouta. 2005. Modelling skewed data with many zeros: a simple approach combining ordinary and logistic regression. Environmental and Ecological Statistics 12: 45-54.

Gibson, D., and B. Isakssen. 1998. Functionality of a full-sized marine mammal exclusion device. Science for Conservation 81.

Gilman, E., N. Brothers and D. R. Kobayashi. 2005. Principles and approaches to abate seabird by-catch in longline fisheries. Fish and Fisheries 6(1): 35-49.

Gonzalez-Zevallos, D., P. Yorio, G. Caille. 2007. Seabird mortality at trawler warp cables and a proposed mitigation measure: a case study in Golfo San Jorge, Patagonia, Argentina. Biological Conservation 136: 108-116.

Gosliner, M. L. 1999. The tuna-dolphin controversy. *In* J.R. Twiss and R. R. Reeves, eds. Conservation and Management of Marine Mammals. Smithsonian Institution Press, Washington: 120-155.

Goudey, C. A. 1995. The 1995 experimental pair trawl fishery for tuna in the Northwest Atlantic. MIT Sea Grant College Program, Report for NOAA Grant NA46RG0434.

Grant, S. and F. Berkes. 2007. Fisher knowledge as expert system: A case from the longline fishery of Grenada, the Eastern Caribbean. Fisheries Research 84: 162-170.

Guisan, A., T. C. Edwards, Jr. and T. Hastie. 2002. Generalized linear and generalized additive models in studies of species distributions: setting the scene. Ecological Modelling 157: 89-100.

Hall, M. A. 1996. On bycatches. Reviews in Fish Biology and Fisheries 6: 319-352.

Hall, M. A. 1998. An ecological view of the tuna-dolphin problem: impacts and trade-offs. Reviews in Fish Biology and Fisheries 8: 1-34.

Hall, M. A., D. L. Alverson and K. I. Metuzals. 2000. By-catch: problems and solutions. Marine Pollution Bulletin 41(1-6): 204-219.

Hall, G. B. and C. H. Close. 2007. Local knowledge assessment for a small-scale fishery using geographic information systems. Fisheries Research 83: 11-22.

Hall-Arber, M. and J. Pederson. 1999. Habitat observed from the decks of fishing vessels. Fisheries 24(6): 6-13.

Hartley, T. W. and R. A. Robertson. 2006a. Emergence of multi-stakeholder-drive cooperative research in the Northwest Atlantic: the case of the Northeast Consortium. Marine Policy 30: 580-592.

Hartley, T. W. and R. A. Robertson. 2006b. Stakeholder engagement, cooperative fisheries research and democratic science: the case of the Northeast Consortium. Human Ecology Review 13(2): 161-171.

Hartmann, M. G., A. S. Couperus, and M. J. Addink. 1996. The diagnosis of by-catch: preliminary results of research in the Netherlands. *In* Kuiken, T.,ed. Diagnosis of by-catch in cetaceans: Proceedings of the second ECS workshop on cetacean pathology. Montpellier, France, 2 March 1994. 43 pp.

Hilborn, R. and M. Mangel. 1997. The Ecological Detective, Confronting Models with Data. Princeton University Press, Princeton. 315 pp.

Hilborn, R., K. Stokes, J.-J. Maguire, T. Smith, L. W. Botsford, M. Mangel, J. Orensanz, A. Parma, J. Rice, J. Bell, K. L. Cochrane, S. Garcia, S. J. Hall, G. P. Kirkwood, K. Sainsbury, G. Stefansson and C. Walters. 2004. When can marine reserves improve fisheries management? Ocean & Coastal Management 47: 197-205.

Kastelein, R. A., D. d. Haan, C. Staal, and A. D. Goodson. 1997a. The response of a harbour porpoise (*Phocoena phocoena*) to nets of various mesh sizes, with and without deterring sound. *In* A.J. Read, P.R. Wiepkema, and P.E. Nachtigall, eds. The biology of the harbour porpoise. De Spil Publishers, Woerden, The Netherlands: 385-409.

Kastelein, R. A., D. d. Haan, A. D. Goodson, C. Staal, and N. Vaughan. 1997b. The effects of various sounds on a harbour porpoise (*Phocoena phocoena*). *In* A.J. Read, P.R. Wiepkema, and P.E. Nachtigall, eds. The biology of the harbour porpoise. De Spil Publishers, Woerden, The Netherlands: 367-384.

Kenney, R. D., and H. E. Winn. 1986. Cetacean high-use habitats of the Northeast United States continental Shelf. Fishery Bulletin 84(2):345-357.

King, G. and L. Zeng. 2001. Logistic Regression in Rare Events Data. Political Analysis 9(2): 137-163.

Kraus, S. D., A. J. Read, A. Solow, K. Baldwin, T. Spradlin, E. Anderson, and J. Williamson. 1997. Acoustic alarms reduce porpoise mortality. Nature 388: 525.

Krueger, R. A. and M. A. Casey. 2000. Focus Groups, A Practical Guide for Applied Research. Third Edition. Sage Publications, Inc., Thousand Oaks. 215 pp.

Krueger, R. A. and J. A. King. 1998. Involving Community Members in Focus Groups. Focus Group Kit 5. Sage Publications, Thousand Oaks. 94 pp.

Larsen, B. H., and C. N. Holm. 1996. Microscopical examination of bronchial fluid from harbour porpoises (*Phocoena phocoena*) for the presence of marine flora and fauna and mineral grains as a possible method to diagnose by-catch. *In* Kuiken, T., ed. Diagnosis of by-catch in cetaceans: Proceedings of the second ECS workshop on cetacean pathology. Montpellier, France, 2 March 1994. 43 pp.

Latimer, A. M., S. Wu, A. E. Gelfand and J. John A. Silander. 2006. Building statistical models to analyze species distributions. Ecological Applications 16(1): 33-50.

Leatherwood, S. 1975. Some observations of feeding behavior of bottle-nosed dolphins (*Tursiops truncatus*) in the northern Gulf of Mexico and (*Tursiops* cf *T. gilli*) off Southern California, Baja California, and Nayarit, Mexico. Marine Fisheries Review 37(9): 10-16.

Lien, J., C. Hood, D. Pittman, P. Ruel, D. Borggaard, C. Chisholm, L. Wiesner, T. Mahon, and D. Mitchell. 1995. Field tests of acoustic devices on groundfish gillnets: assessment of effectiveness in reducing harbour porpoise by-catch. *In* R.A. Kastelein, J.A. Thomas, and P.E. Nachtigall, eds. Sensory Systems of Aquatic Mammals. De Spil Publishers, Woerden, The Netherlands: 349-364.

Lipscomb, T. P. 1996. Pathologic findings in dolphins known to have died from underwater entrapment. *In* Kuiken, T., ed. Diagnosis of by-catch in cetaceans: proceedings of the second ECS workshop on cetacean pathology. Montpellier, France, 2 March 1994. 43 pp.

Loughlin, T. R., L. Consiglieri, R. L. Delong, and A. T. Actor. 1983. Incidental catch of marine mammals by foreign fishing vessels, 1978-81. Marine Fisheries Review 45(7-8-9): 44-49.

MacKenzie, D. I., J. A. Royle, J. A. Brown and J. D. Nichols. 2004. Occupancy estimation and modeling for rare and elusive populations. *In* Thompson, W.L. Sampling rare or elusive species. Island Press, Washington: 149-172.

Macnab, P. 1998. There must be a catch: participatory GIS in a Newfoundland fishing community. Paper for the NCGIA Specialist Meeting: Empowerment, Marginalization and Public Participation GIS, October 15^{th}-17^{th}, 1998.

Maigret, J. 1994. Marine mammals and fisheries along the West African coast. Report of the International Whaling Commission, Special Issue 15: 307-316.

Maravelias, C. D. 1997. Trends in abundance and geographic distribution of North Sea herring in relation to environmental factors. Marine Ecology Progress Series 159: 151-164.

Martin, T. G., B. A. Wintle, J. R. Rhodes, P. M. Kuhnert, S. A. Field, S. J. Low-Choy, A. J. Tyre and H. P. Possingham. 2005. Zero tolerance ecology: improving ecological inference by modeling the source of zero observations. Ecology Letters 8: 1235-1246.

Mayer, D., D. Roy, J. Robins, I. Halliday and M. Sellin. 2005. Modelling zero-inflated fish counts in estuaries – a comparison of alternate statistical distributions. *In* Zerger, A. and Argent, R.M. , eds. MODSIM 2005 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2005: 2581-2586. Available at http://www.mssanz.org.au/modsim05/proceedings/papers/mayer.pdf.

McDaniel, C. J., L. B. Crowder, and J. A. Priddy. 2000. Spatial dynamics of sea turtle abundance and shrimping intensity in the U.S. Gulf of Mexico. Conservation Ecology 4(1): 15.

McDonald, L. L. 2004. Sampling rare populations. *In* Thompson, W.L. Sampling rare or elusive species. Island Press, Washington: 11-42.

Meyer, T. L., R. A. Cooper, and R. W. Langton. 1979. Relative abundance, behavior, and food habits of the American sand lance, *Ammodytes americanus*, from the Gulf of Maine. Fishery Bulletin 77(1):243-253.

Minami, M., C. E. Lennert-Cody, W. Gao and M. Roman-Verdesoto. 2007. Modeling shark bycatch: the zero-inflated negative binomial regression model with smoothing. Fisheries Research 84: 210-221.

Moller, H., F. Berkes, P. O. Lyver and M. Kislalioglu. 2004. Combining science and traditional ecological knowledge: monitoring populations for co-management. Ecology and Society 9(3): 2.

Morgan, D. L. 1998. The Focus Group Guidebook. Focus Group Kit 1. Sage Publications, Thousand Oaks. 103 pp.

Morizur, Y., S. D. Berrow, N. J. C. Tregenza, A. S. Couperus, and S. Pouvreau. 1999. Incidental catches of marine-mammals in pelagic trawl fisheries of the northeast Atlantic. Fisheries Research 41: 297-307.

Mountain, D. 1989. TEMPEST, A computer program for estimating temperature on the Northeast continental shelf. Northeast Fisheries Center Reference Document 89-02. NOAA, NMFS, Northeast Fisheries Center, Environmental Processes Division, 8 pp.

Murawski, S.A., A.M. Lange, M.P. Sissenwine, and R.K. Mayo. 1983. Definition and analysis of multispecies otter-trawl fisheries off the northeast coast of the United States. ICES Journal of Marine Science 41(1): 13-27.

Murawski, S.A. and J.T. Finn. 1988. Biological bases for mixed-species fisheries: species co-distribution in relation to environmental and biotic variables. Canadian Journal of Fisheries and Aquatic Sciences 45:1720-1735.

Murray, K. T. 2004. Bycatch of sea turtles in the Mid-Atlantic sea scallop (*Placopecten magellanicus*) dredge fishery during 2003. 2nd edition. U.S. Department of Commerce, Northeast Fisheries Science Center Reference Document 04-11; 25 pp. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

Murray, K. T., A. J. Read, and A. R. Solow. 2000. The use of time/area closures to reduce bycatches of harbour porpoises: lessons from the Gulf of Maine sink gillnet fishery. Journal of Cetacean Research and Management 2(2): 135-141.

NMFS (National Marine Fisheries Service). 2004. Evaluating bycatch: a national approach to standardized bycatch monitoring programs. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-66. 108 pp. Accessed December 2007. Available from http://spo.nmfs.noaa.gov/tm/tm66.pdf

NOAA (National Oceanic and Atmospheric Administration). 2002. Marine mammal stock assessment report: White-sided Dolphin (*Lagenorhynchus acutus*), Western North Atlantic Stock. National Marine Fisheries Service, Silver Spring, Maryland. Accessed September 2008. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2002dows-wn.pdf

NOAA (National Oceanic and Atmospheric Administration). 2005. Marine mammal stock assessment report: White-sided Dolphin (*Lagenorhynchus acutus*), Western North Atlantic Stock. National Marine Fisheries Service, Silver Spring, Maryland. Accessed March 2007. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2005dows-wn.pdf

NOAA (National Oceanic and Atmospheric Administration). 2007. Marine mammal stock assessment report: White-sided Dolphin (*Lagenorhynchus acutus*), Western North Atlantic Stock. National Marine Fisheries Service, Silver Spring, Maryland. Accessed October 2008. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2007dows-wn.pdf

Neis, B., D.C. Schneider, L. Felt, R.L. Haedrich, J. Fischer, and J.A. Hutchings. 1999. Fisheries assessment: what can be learned from interviewing resource users? Canadian Journal of Fisheries and Aquatic Sciences 56: 1949-1963.

Northridge, S. 1988. Marine mammals and fisheries: a study of conflicts with fishing gear in British waters. A report commissioned by Wildlife Link's Seals Group. 140 pp.

Northridge, S. P. 1991. An updated world review of interactions between marine mammals and fisheries. FAO Fisheries Technical Paper No. 734, Suppl. 1. Food and Agriculture Organization of the United Nations, Rome, Italy. 58 pp.

Northridge, S. 2003a. Reduction of cetacean bycatch in pelagic trawls. Final Report to DEFRA & JNCC, Project MF0733.

Northridge, S. 2003b. Further development of a dolphin exclusion device. Final Report to DEFRA, Project MF0735.

Northridge, S., M. Tasker, A. Webb, K. Camphuysen, and M. Leopold. 1997. White-beaked *Lagenorhynchus albirostris* and Atlantic white-sided dolphin *L. acutus* distributions in Northwest European and US North Atlantic waters. Reports of the International Whaling Commission 47: 797-805.

Northridge, S. P. and R. J. Hofman. 1999. Marine mammal interactions with fisheries. *In* Twiss, J.R. and R. R. Reeves, eds. Conservation and Management of Marine Mammals. Smithsonian Institution Press, Washington: 99-119.

Northridge, S., D. Sanderson, A. Mackay, and P. Hammond. 2003. Analysis and mitigation of cetacean bycatch in UK fisheries. Final Report to DEFRA, Project MF0726.

Northridge, S., A. Mackay, D. Sanderson, R. Woodcock, and A. Kingston. 2004. A review of dolphin and porpoise bycatch issues in the Southwest of England. An occasional report to the Department for Environment Food and Rural Affiars.

Pace, D. S., M. Pulcini, and F. Triossi. 2003. Interactions with fisheries: modalities of opportunistic feeding for bottlenose dolphins at Lampedusa Island. Proceedings of the 17th Annual Conference of the European Cetacean Society (Las Palmas de Gran Canaria, Spain, 9-13 March 2003).

Palka, D., A. Read, and C. Potter. 1997. Summary of knowledge of white-sided dolphins (*Lagenorhynchus acutus*) from the U.S. and Canadian and North Atlantic waters. Rep. Int. Whal. Commn 47: 729-734.

Perry, R. I. and S. J. Smith. 1994. Identifying habitat associations of marine fishes using survey data: an application to the Northwest Atlantic. Canadian Journal of Fisheries and Aquatic Sciences 51: 598-601.

Quinn, N. 2005. Introduction. *In* Quinn, N. Finding culture in talk: a collection of methods. Palgrave Macmillan, New York: 1-34.

Rea, L.M. and R.A. Parker. 1997. Designing and Conducting Survey Research. Jossey-Bass Publishers, San Francisco. 254 pp.

Read, A.J. 2005. By-catch and depredation. *In* J.E. Reynolds et al., eds. Marine Mammal Research: Conservation beyond Crisis. The Johns Hopkins University Press, Baltimore, Maryland.

Read, A. J. and A. A. Rosenberg (convenors). 2002. Draft International Strategy for Reducing Incidental Mortality of Cetaceans in Fisheries. Accessed on March 14, 2005. Available at http://cetaceanbycatch.org/intlstrategy.cfm.

Read, A. J., P. Drinker and S. Northridge. 2006. Bycatch of marine mammals in U.S. and global fisheries. Conservation Biology 20(1): 163-169.

Redfern, J. V., M. C. Ferguson, E. A. Becker, K. D. Hyrenbach, C. Good, J. Barlow, K. Kaschner, M. F. Baumgartner, K. A. Forney, L. T. Ballance, P. Fauchald, P. Halpin, T. Hamazaki, A. J. Pershing, S. S. Qian, A. Read, S. B. Reilly, L. Torres and F. Werner. 2006. Techniques for cetacean-habitat modeling. Marine Ecology Progress Series 310: 271-295.

Rogers, D.R., B.D. Rogers, J.A. de Silva, and V.L. Wright. 1997. Effectiveness of four industry-developed bycatch reduction devices in Louisiana's inshore waters. Fishery Bulletin 95(3): 552-565.

Sea Grant. 2003. Trawlers. Sea Grant Oregon. Accessed on December 9, 2004. Available at http://seagrant.oregonstate.edu/sgpubs/onlinepubs/g03007.pdf.

Selzer, L. A., and P. M. Payne. 1988. The distribution of white-sided (*Lagenorhynchus acutus*) and common dolphins (*Delphinus delphis*) vs. environmental features of the continental shelf of the northeastern United States. Marine Mammal Science 4(2):141-153.

Sequeira, M., and C. Ferreira. 1994. Coastal fisheries and cetacean mortality in Portugal. Report of the International Whaling Commission, Special Issue 15. p. 165-181.

Scholz, A., K. Bonzon, R. Fujita, N. Benjamin, N. Woodling, P. Black and C. Steinback. 2004. Participatory socioeconomic analysis: drawing on fishermen's knowledge for marine protected area planning in California. Marine Policy 28(4): 335-349.

Shane, S. H., R. S. Wells, and B. Wursig. 1986. Ecology, behavior and social organization of the bottlenose dolphin: a review. Marine Mammal Science 2(1): 34-63.

Siebert, U., H. Benke, K. Frese, F. Pirro, and R. Lick. 1996. Postmortem examination of by-catches from German fisheries and of suspected by-catches found on the coast of Germany. *In* Kuiken, T. (ed.). Diagnosis of by-catch in cetaceans: Proceedings of the second ECS workshop on cetacean pathology. Montpellier, France, 2 March 1994. 43 pp.

Slooten, E., and S. M. Dawson. 1995. Conservation of marine mammals in New Zealand. Pacific Conservation Biology 2: 64-76.

St. Martin, K. 2001. Making space for community resource management in fisheries. The Annals of the Association of American Geographers 91(1): 122-142.

St. Martin, K. and M. Hall-Arber. 2006. Charting fishing communities at sea: revealing new potentials for participation in fisheries science and management. Paper presented at ICES 2006, Fishing Technology in the 21st Century, Boston, MA, 30 October–3 November.

St. Martin, K., B. J. McCay, G. Murray, T. Johnson and B. Oles. 2007. Communities, knowledge and fisheries of the future. International Journal of Global Environmental Issues 7(2-3): 221-239.

Stefansson, G. 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. ICES Journal of Marine Science 53: 577-588.

SGFEN (Subgroup on Fishery and Environment). 2002. Incidental catches of small cetaceans. Report of the second meeting of the subgroup on fishery and environment (SGFEN) of the scientific, technical, and economic committee for fisheries (STECF), Brussels, 11-14 June 2002. Commission Staff Working Paper, Commission of the European Communities. SEC(2002) 1134. 63pp.

Sullivan, B.J., P. Brickle, T.A. Reid, D.G. Bone, and D.A.J. Middleton. 2006. Mitigation of seabird mortality on factory trawlers: trials of three devices to reduce warp cable strikes. Polar Biology 29: 745-753.

Summers, E. 2002. The distribution of Atlantic white-sided dolphins, *Lagenorhynchus acutus*, in the Gulf of Maine: A predictive model. Master's thesis, Boston University. 72 pp.

TRT (Take Reduction Team). 2006. Unpublished data presented at the Atlantic Trawl Gear Take Reduction Team meeting. National Oceanic and Atmospheric Administration, September 2006.

TRT (Take Reduction Team). 2007. Unpublished data presented at the Atlantic Trawl Gear Take Reduction Team meeting. National Oceanic and Atmospheric Administration, April 2007.

Tregenza, N. J. C., and A. Collet. 1998. Common dolphin *Delphinus delphis* bycatch in pelagic trawl and other fisheries in the North East Atlantic. Report of the International Whaling Commission 48:453-459.

Tyler, S. R. 1999. Policy implications of natural resource conflict management. *In* Buckles, D. Cultivating Peace: Conflict and Collaboration in Natural Resource Management. International Development Research Centre, Ottawa: 263-280.

Waring, G.T., P. Gerrior, P.M. Payne, B.L. Parry, and J.R. Nicolas. 1990. Incidental take of marine mammals off the Northeast United States, 1977-88. Fishery Bulletin 88: 347-360.

Wiebe, P., D. Mountain, and A. Bucklin. 2002. U.S. GLOBEC Northwest Atlantic/Georges Bank Program. Oceanography 15(2): 13-29.

Wilson, D. C. 1999. Fisheries science collaborations: the critical role of the community. Institute for Fisheries Management and Coastal Community Development, Research Publication No. 45. Keynote presentation at the Conference on Holistic Management and the Role of Fisheries and Mariculture in the Coastal Community Nov 11-12, 1999, Tjarno Marine Biological Laboratory, Sweden.

Young, Nina. 2001. The conservation of marine mammals using a multi-party approach: an evaluation of the take reduction team process. Ocean and Coastal Law Journal 6(2): 293-346.

Zar, J. H. 1996. Biostatistical Analysis. Third Edition. Prentice Hall, New Jersey. 662 pp.

Zollett, E.A. and A.J. Read. 2006. Depredation of catch by bottlenose dolphins (*Tursiops truncatus*) in the Florida king mackerel (*Scomberomorus cavalla*) troll fishery. Fishery Bulletin 104(3): 343-349.

APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL

University *of* New Hampshire

Research Conduct and Compliance Services, Office of Sponsored Research
Service Building, 51 College Road, Durham, NH 03824-3585
Fax: 603-862-3564

15-Oct-2007

Zollett, Erika
Natural Resources
OPAL, 142 Morse Hall
238 Miller Avenue
Portsmouth, NH 03801

IRB #: 4082
Study: Developing conservation techniques to reduce Atlantic white-sided dolphin bycatch in the Northwest Atlantic bottom trawl fishery
Approval Date: 15-Oct-2007

The Institutional Review Board for the Protection of Human Subjects in Research (IRB) has reviewed and approved the protocol for your study as Exempt as described in Title 45, Code of Federal Regulations (CFR), Part 46, Subsection 101(b). Approval is granted to conduct your study as described in your protocol.

Researchers who conduct studies involving human subjects have responsibilities as outlined in the attached document, *Responsibilities of Directors of Research Studies Involving Human Subjects.* (This document is also available at http://www.unh.edu/osr/compliance/irb.html.) Please read this document carefully before commencing your work involving human subjects.

Upon completion of your study, please complete the enclosed pink Exempt Study Final Report form and return it to this office along with a report of your findings.

If you have questions or concerns about your study or this approval, please feel free to contact me at 603-862-2003 or Julie.simpson@unh.edu. Please refer to the IRB # above in all correspondence related to this study. The IRB wishes you success with your research.

For the IRB,

Julie Simpson

Julie F. Simpson
Manager

cc: File
Rosenberg, Andrew

APPENDIX B:

INTERVIEW INFORMED CONSENT

INFORMED CONSENT

The information gathered from this interview will be used in my doctoral dissertation at the University of New Hampshire. The purpose of this research is to develop a method to incorporate detailed knowledge from fishermen in developing scientific advice for management and therefore to give fishermen a greater voice in fisheries management. My aim is to work with fishermen to identify potential bycatch reduction strategies that are based on fishermen's knowledge of the ecosystem, are effective while minimizing negative impacts to fishing operations, and have the support of the fishermen.

The interview, which should take approximately one hour, contains questions about your fishing experiences, and I have maps that you are free to draw on if it will help you answer the questions. There are no correct or incorrect responses, so please feel free to express your opinions. I view you as the expert, helping me to understand what happens on the ocean. Your participation is voluntary. You may skip any question you prefer not to answer. You may also end the interview at any time.

The answers you give me will be confidential – the information you provide me will not be connected with your name. I will record our conversations with your permission, and I will be the only person to listen to the recordings. The recordings will be destroyed at the completion of the study.

Should you have any questions after this interview about the research, you may reach me (Erika Zollett) at 603-862-2396. To learn more about the rights of research subjects, you may call the Office of Sponsored Research at the University of New Hampshire at 603-862-2003.

If you understand and agree to continue with this interview, we may begin now.

APPENDIX C:

INTERVIEW GUIDING QUESTIONS

General Questions

1. Are you the captain, owner, crew?
2. What is your homeport?
3. What is the size of your boat?
   < 50 feet 50-70 feet > 70 feet
4. How long have you been commercial fishing?
5. What has been your primary gear type within the last 20 years?
6. Have you regularly used another type of gear?

*For this interview, I am specifically interested in your bottom trawl experiences.

7. What months do you use bottom trawl gear? When?
8. What is the typical length of your fishing trips?
   1 day 2-3 days > 3 days
9. What primary species do you normally target in each of the seasons?
10. How far offshore do you normally fish?
    <20 miles 20-50 miles > 50 miles
11. What do you call your primary fishing area?
    a. Western Gulf of Maine (includes Middle Bank, Stellwagen, Jeffrey's, MA and Ipswich Bay)
    b. Wilkinson's Basin
    c. Eastern Gulf of Maine
    d. Offshore, greater than 50 miles (includes Great South Channel, Georges Bank)
    e. Southern New England (South and West of Great South Channel, Point Judith area)
    f. Midcoast Maine
12. What depth do you usually fish on?
13. Do you fish flounder gear or rockhopper gear?

Ecological Questions

14. How often do you see dolphins on the surface when you are fishing?
15. Do you see more than one kind of dolphin?
16. Where do you normally see them?
17. Do you usually see dolphins associated with bait species?
    a. If yes, do you know what species of bait?
18. Are you more likely to see them during certain seasons?
19. What about during a particular time of day?
20. Have you noticed if they are around more often in certain weather?
21. How about bottom types or depth? Contour?
22. I also wonder if you have noticed whether dolphins are more likely to be around when you are targeting a particular species.
    a. If yes, what species?
    b. Is that species associated with a certain temperature? Bottom type? Depth?
23. What are the dolphins doing when you see them?

24. Do you see dolphins when you are setting the gear, fishing, hauling or at other particular times during your fishing?

Bycatch Questions

25. Bycatch records show that dolphins are occasionally caught in fishing gear. Have you ever caught one?
    a. If yes, what happened?
        1. Do you think the animal was alive when it entered the net?
        2. Did it create a problem for you?
        3. Was it hard to get the animal out of your gear?
        4. How often has this happened?

    b. If no, have you heard of anyone else from your port catching a dolphin?
        1. What did they do?
26. I have a map here that shows where the observer program data suggests the conditions exist for dolphin bycatch to occur. This map is based on observer records from 1996-2005 for the months of March and April. These maps are based on a model that includes sea surface temperature, depth, and an interaction between slope and depth.
    1. Do you agree with this?
        i. (IF YES) Do you experience dolphin bycatch in these areas?
        ii. (IF YES) From your experiences, can you show me where you think it is more likely to occur? Why?
        (optional) Can you be more specific about which part of that fishing area?
        iii. (IF YES) From your experiences, is dolphin bycatch related to SST, depth, slope?
        iv. (IF YES OR NO) Are there areas that are not shown on here where dolphin bycatch occurs or where you think it is likely?
    2. (IF YES OR NO) Are there any areas that you avoid because you are concerned about dolphin bycatch? (i.e. see a lot of dolphins in an area)
    3. You mentioned earlier that you tended to see more dolphins when fishing in/at/for ___________. Is this also when you or other fishermen are more likely to catch a dolphin?
        A. Have you experienced or heard from other fishermen that dolphin bycatch occurs:
            i. At specific times of year? If so, when?
            ii. Specific times of day?
            iii. Particular times during your fishing? Such as during setting or hauling? Turns? Fast haulbacks?
            iv. Do you notice any other pattern to when dolphin bycatch occurs?
27. (SUMMARIZE) I want to make sure I got this right, from what you've said it seems like the biggest problem for dolphin bycatch happens …

Mitigation Questions

28. Have you noticed what the dolphins are doing when they are caught?
29. Do you have ideas on how to reduce catch of dolphins in bottom trawl gear?
    a. Gear modification?
    b. What about changing where, when, or how you fish (i.e depth or speed)?
    c. Have you heard that fishermen in other areas voluntarily communicate with each other where bycatch occurs so they can avoid fishing in those areas?
        i. Would that be feasible for you?
        ii. Do you normally communicate with other fishermen about what you are catching and where?
        iii. What information would you be willing to share? Dolphin bycatch locations?
        iv. With whom?
30. Which of these ideas would work best for you?
31. Which do you think would be best at reducing dolphin bycatch?
32. How would you suggest making that work?
    a. Would you suggest requiring that?
    b. How would most fishermen respond?
    c. Would it be unfair to some but not others?